DECEMBER 1958

THE WELDING JOURNAL

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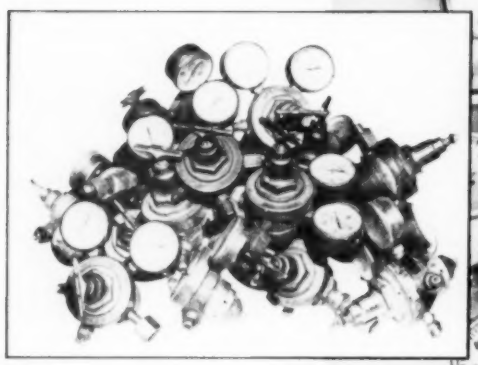

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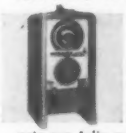

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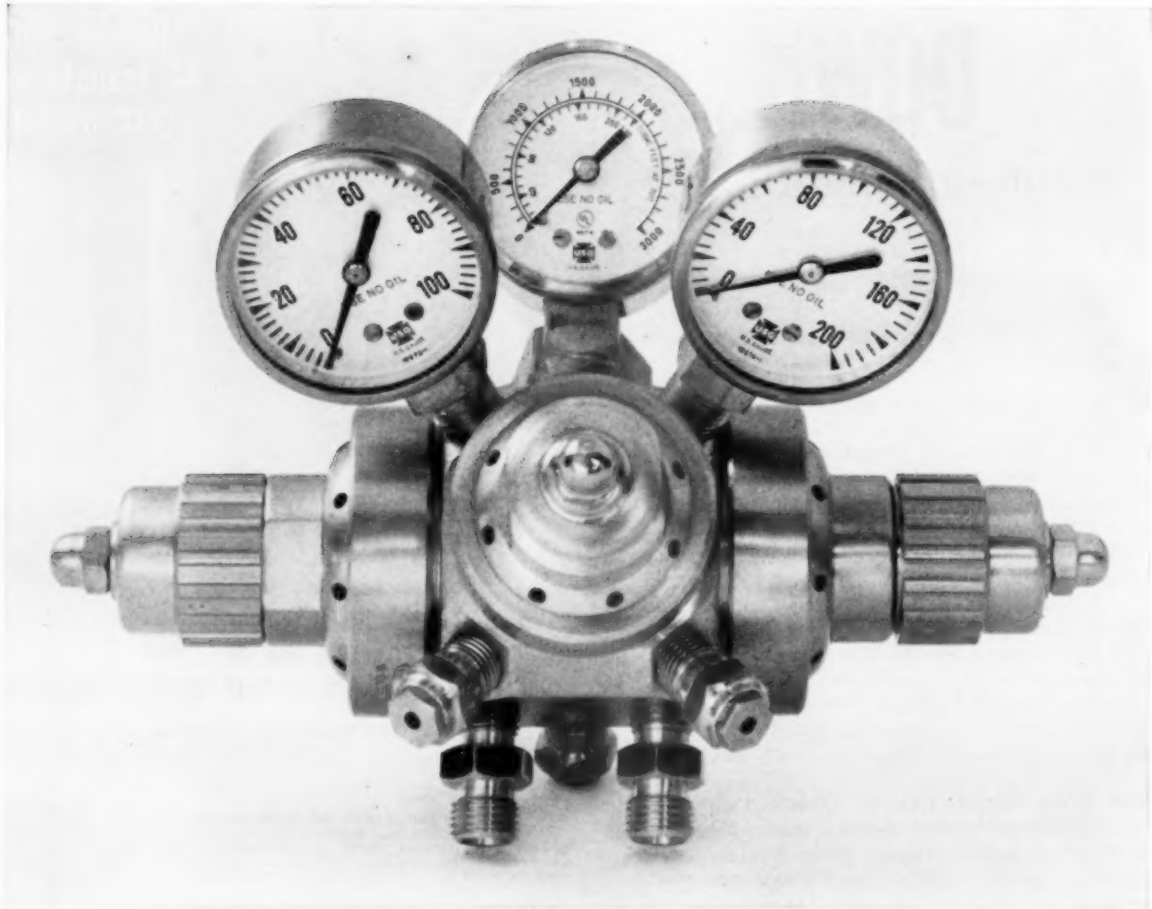

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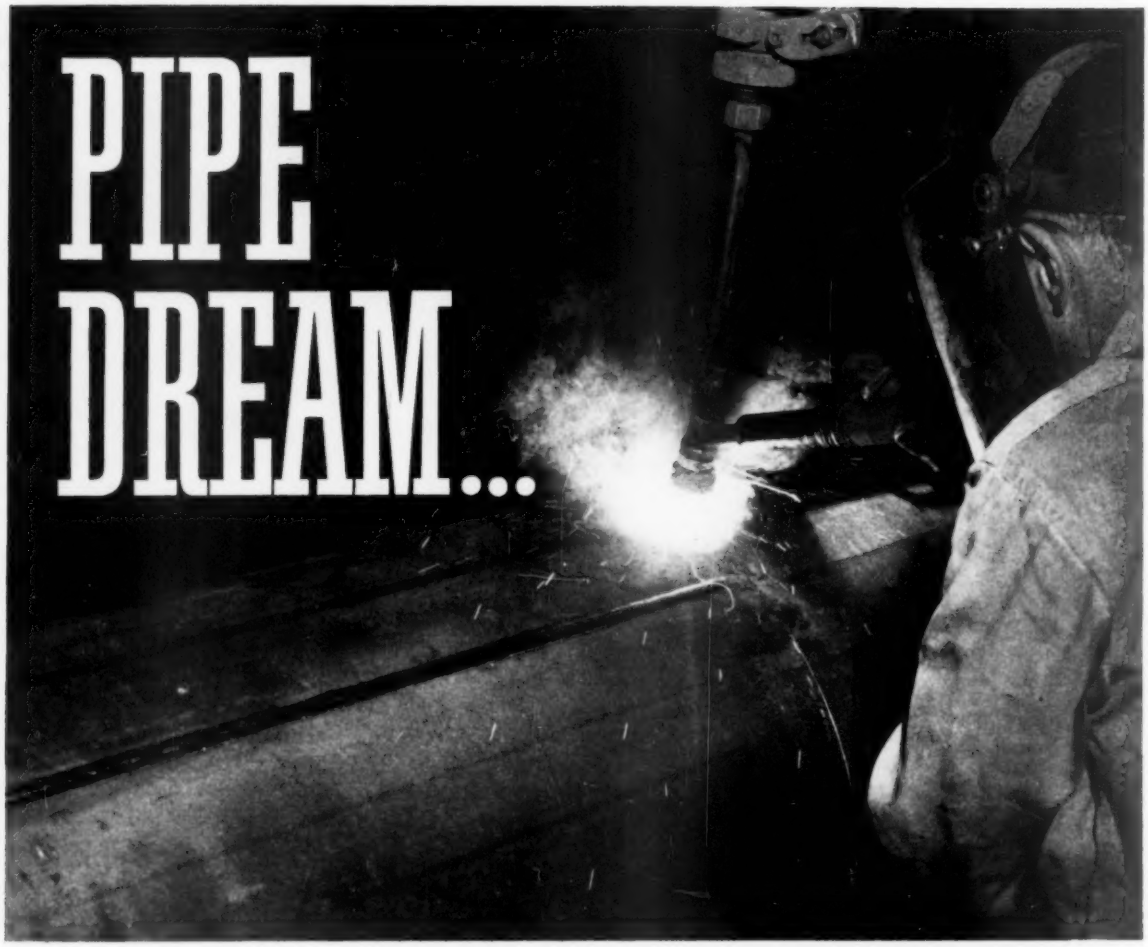

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EDITORIAL

GREATER USEFULNESS THROUGH WELDING

Welding processes have had significant acceptance in the last 40 years. Welding was considered an art in the early days, and now most welding procedures are subjected to exacting scientific controls to promote uniformity and dependability. This operation has become an acceptable versatile process in the steel industry where most every known method of welding is being practiced.

There are a number of production welding operations performed in steel plants. As an example, tubular products welded by different methods are used universally to improve the living standards for all human beings. In another case, resistance welding has improved the usefulness of flat-rolled products by increasing efficiency and productivity for both steel producers and fabricators. Generally, industrial progress has become dependent upon the advances and improvements in welding techniques.

Steel melting practices have been modified and controlled to provide materials that will respond properly in welding operations. Welding has become, in addition, a very important maintenance tool in any steel plant. This operation is used repeatedly for repairs to operating equipment and, in many cases, time lost in costly breakdowns is minimized by resorting to some form of welding. Worn equipment is rebuilt with welding materials to provide built-up areas and new wearing surfaces.

The acceptance of specialty steels and of new metals, such as stainless steel and titanium, is dependent upon the successful development of welding techniques. It is important, then, to continue research into every phase of joining metals.

Welding research problems enumerated in the August 1958 issue of the *Welding Research Supplement* deserve critical attention. These problems cover every related item beginning with materials, welding equipment, procedures, physical characteristics, stress analyses, application and inspection. Economical nondestructive methods of inspection of the quality of welds are extremely important. The Welding Research Council is sponsoring activity in many of these areas. The reports issued by individuals and institutions studying such projects have provided valuable information which indicates that these studies should be continued.

Welding is a vital process in our economy and merits the sustained interest of all industry.

E. R. Johnson
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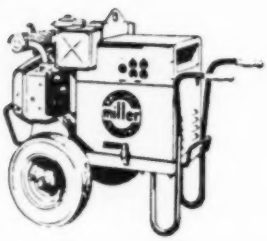

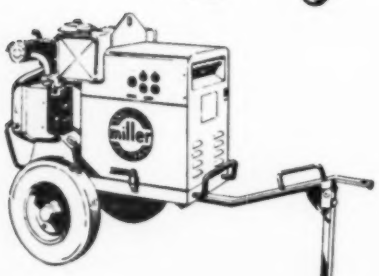

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Fig. 1 Collapsible welding chamber (courtesy of the Bureau of Mines)

CONTROLLED-ATMOSPHERE ARC WELDING

Some of the general considerations of controlled-atmosphere arc welding, shielding systems open to the atmosphere, and systems closed to the atmosphere are discussed

BY N. E. WEARE AND R. E. MONROE

ABSTRACT. Many of the new engineering metals coming into widespread use in welding applications are sensitive to contamination by gaseous impurities such as oxygen, nitrogen or hydrogen. These metals and alloys may become embrittled or less resistant to corrosion because of gaseous impurities picked up during welding. Carefully controlled welding atmospheres are required to prevent harmful contamination of metals such as zirconium, titanium, molybdenum, hafnium, niobium and tantalum. The design, construction and operation of various types of equipment for preventing such contamination are discussed in this paper. Controlled-atmosphere equipment may range from large vacuum-purged dry boxes to simple trailing shields for use with standard welding torches. Shielding equipment for open-air use includes cups, trailing and leading shields, dragging shields, and gas backups. Closed-atmosphere equipment discussed includes both flow-purged and vacuum-purged enclosures.

Introduction

Arc welding is always conducted in some type of gaseous atmosphere. This atmosphere may be generated from fluxes, supplied from a cylinder, or may simply be air. As arc welding developed from bare wire and covered electrodes for welding steels to inert-gas-shielded processes for welding metals such as aluminum, zirconium and titanium, greater control and efficiency of gas shielding has become important. Controlled-atmosphere arc welding, as discussed in this paper, will be limited to welding operations in essentially inert atmospheres. This paper presents a summary of recent developments in this area, with emphasis on techniques involving shielding in addition to that obtained with simple shielding cups. Weld shielding with carbon dioxide and other gases which may show inert behavior under special conditions* is not included in this paper. However, the term "controlled-atmosphere welding" also applies to the use of these gases.

Widespread use of shielding of the molten weld pool with inert gas is a relatively recent development in the

N. E. Weare is a Principal Welding Engineer and **R. E. Monroe** is an Assistant Chief associated with the Metals Joining Division, Battelle Memorial Institute, Columbus, Ohio.

Paper presented at 1958 AWS Annual Spring Meeting held in St. Louis, Mo., April 14–18.

* Nitrogen is an inert atmosphere for welding copper.

welding industry. The first welding process to utilize commercially an inert-gas shield to protect the weld pool was the tungsten-arc process introduced in the aircraft industry in the early 1940's. At that time, it was considered only a manual process which had solved some of the problems involved in welding magnesium alloys. A few years after the appearance of the tungsten-arc process, the inert-gas-shielded consumable-electrode process was developed. Research in arc theory and improvements in shielding-gas purity and shielding methods have prompted many developments, so that today the inert-gas-shielded welding processes are applied to the welding of more metals than any other arc-welding process. In these processes, the electrode, arc column, molten weld pool, and, in the case of a consumable electrode, the metal being transferred through the arc, are shielded by flowing inert gas. Argon and helium are the only truly inert gases commercially used for welding, but mixtures of these with oxygen or hydrogen are used for special applications.

In recent years, many new materials have come into widespread use, because they possess properties which make them desirable for use in atomic energy, missile and jet-aircraft applications. Properties such as ductility or corrosion resistance of zirconium, titanium, molybdenum, niobium, tantalum and similar reactive metals are lowered when the metals are contaminated with small amounts of gaseous impurities. These impurities, primarily oxygen, nitrogen and hydrogen, which are picked up from air, contaminate welds in these metals that are not shielded from air.[1,2] The degree of shielding required in welding reactive metals depends to some extent on the specific application. Generally, better shielding is required for reactive metals than for materials such as aluminum or steel. Initial improvement in weld shielding of reactive materials was made by adding trailing shields to the standard shielding cups. These provided gas coverage of weld metal which was still hot enough to be contaminated when exposed to air. Flowing inert-gas shields were further improved by the development of: (1) gas backups to protect the root side of the weld; (2) leading shields, generally used in conjunction with trailing shields, to prevent oxide formation in the joint ahead of the molten weld pool; (3) dragging shields which move in contact with the material being welded and act as small welding chambers; and (4) improved jigging to chill the weldment rapidly after welding to a temperature at which contamination will not occur.

Some materials and components require exceptionally good shielding during welding. In these cases, welding is done in a closed system which is sealed off from the atmosphere. Early systems were generally flow purged of their original atmosphere. However, with the growing need for even better shielding, vacuum-purged systems have come into widespread use.

This paper discusses some of the general considerations of controlled-atmosphere arc welding, shielding systems open to the atmosphere, and systems closed to the atmosphere.

General Considerations

Two problems are common to all controlled-atmosphere arc-welding techniques. These are tests to measure shielding-atmosphere purity and the selection and handling of shielding gases.

The purity of the shielding gas cannot be measured easily at the arc where it is really significant. This fact has forced the use of various indirect measurements which may not appear to be true measures of gas purity. However, if such indirect measurements are properly correlated with the conditions that exist during welding and with final joint properties, they are usually the quickest and cheapest methods of controlling gas purity. In closed systems, the gas can be analyzed, but this is slow and costly. It is also difficult to obtain a sample of gas which is representative of the gas near the arc. Once an arc is started, absorbed and adsorbed gases are released from the materials which become heated. These gases are then free to contaminate the metal being welded. In systems open to the atmosphere, it is nearly impossible to measure shielding-gas purity during the welding operation. Some investigators have used the Schlieren method of determining the area protected by a flowing-gas shield;[3] others have used the aluminum and titanium spot method.[4] In the welding of some materials, the degree of protection provided by the inert-gas shield is indicated by the degree of discoloration of the weldment. With materials such as titanium, zirconium, tantalum, niobium and molybdenum, the tolerance for impurities is so small that the absence of discoloration is not an indication of adequate shielding. For all shielding methods, the best way to determine whether the shielding is adequate is to make and test sample joints. This will indicate whether the degree of contamination is sufficient to affect adversely the desired properties of the joint. Atmosphere purity is expressed in numerous ways with some resulting confusion. Figure 2 shows the relationship between several common terms used to describe gas purity.

Many places exist where the high-purity gas obtained from a gas plant can become contaminated before its use in shielding a weld. Most inert gas used for welding is not sold to a guaranteed purity although one manufacturer recently started such a policy. Slight differences in gas purity usually exist between cylinders of a given gas and, in some cases, suitable cylinders for very high-quality shielding must be selected. Any condensable vapor, such as water, will cause more contamination of shielding gases as the cylinder pressure is lowered. Gas contamination can occur from any vapor that condenses in the gas lines of equipment. In closed systems, condensed vapors are probably the major source of contamination. Contamination from condensed vapors can be minimized by leaving inert gas in the shielding-gas lines. Condensed vapors can be removed from a shielding system by heating during the purging cycle.

Effective shielding of welds made in air can be obtained with either argon or helium. Generally, the flow rate required for helium is 1.5 to 2.5 times the flow

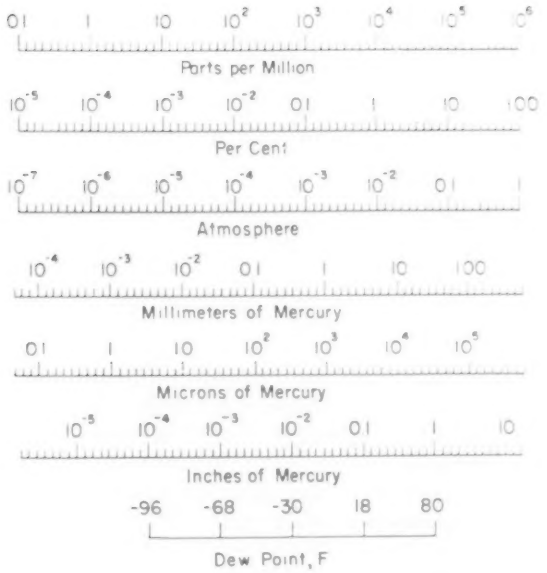
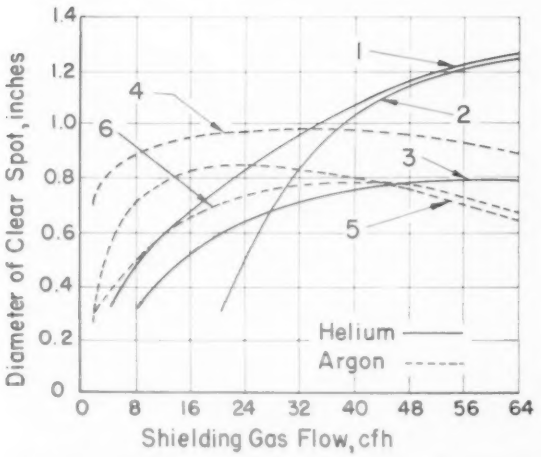


Fig. 2 Comparison of units used to express residual impurities in an atmosphere. (Note that all scales are logarithmic)



Curve Nos.	Nozzle Diam., in.	Nozzle-Work Distance, in.
1 and 4	$\frac{5}{8}$	$\frac{3}{16}$
2 and 5	$\frac{5}{8}$	$\frac{3}{8}$
3 and 6	$\frac{3}{8}$	$\frac{3}{8}$

Fig. 3 Relationship between shielding-gas flow and gas coverage for helium and argon with varying nozzle sizes and nozzle-work distances

rate required using argon under similar conditions. With both gases, the shielding device should be brought as close to the weld as possible to insure adequate exclusion of atmosphere contaminators. Figure 3, drawn from data presented by Gibson[4], illustrates the effect of gas flow on the weld area shielded from the atmosphere for argon and helium, with different nozzle-to-work distances and shielding-cup sizes.

The area shielded with a given nozzle diameter and nozzle-to-work distance increases to a maximum and then decreases when the gas-flow rate is increased. Below this maximum, not enough gas is available to cover the entire area under the nozzle; above the optimum rate (at the maximum area) the flow becomes turbulent and air becomes entrapped in the shield. At a certain distance from the shielding nozzle, the gas flow will change from laminar to turbulent flow which entraps air in the shield. It is for this reason that the nozzle-to-work distance should be held to a minimum. If the nozzle-to-work distance must be increased, the gas flow must also be increased. Since there is an optimum gas-flow rate, it is apparent that there is also a nozzle-to-work distance beyond which adequate shielding cannot be obtained. As the nozzle size is increased, gas flows must be increased proportionately to provide adequate shielding. When proper gas flows are used for the various diameter nozzles in normal use, larger areas can be shielded when larger diameter nozzles are employed. Excessively large-diameter nozzles will not provide a proportional amount of increased shielding and may provide less shielding than a smaller diameter nozzle due to uneven gas flow. When large areas require shielding, leading trailing or dragging shields should be used in conjunction with the shielding cup.

Equipment and Techniques

There are several methods by which normal shielding methods may be improved for the welding of materials easily contaminated by air. Normally, only a shielding cup is used to protect the molten weld metal. Better shielding can be obtained with the equipment and techniques described in the following sections.

Open Shields

Shielding equipment which is used outside of complete enclosures includes shielding cups, trailing shields, dragging shields, gas backups, and special jigs and fixtures. These are discussed more fully below.

Shielding Cups

Shielding cups are standard equipment with all inert-gas-shielded welding torches. These cups are either conical or cylindrical in shape and fit on the welding-torch body concentric with the electrode. This is illustrated in Fig. 4*a*. Cups are generally made of pyrex or a ceramic for low- and medium-current tungsten-arc welding and copper with water cooling for high-current tungsten-arc welding and consumable-electrode welding.

The shielding cup provides excellent protection for the electrode, arc, material being transferred through the arc, and the molten pool. Adequate shielding can be provided by a shielding cup when the weld is small so that all the material not protected by shielding gas is below a temperature at which oxidation or contamination can occur. For most welding applications involving the reactive metals, oxidation or contamination of the metal outside of the shield area will occur. To provide maxi-

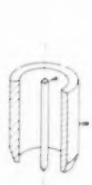


Fig. 4a Shielding cup

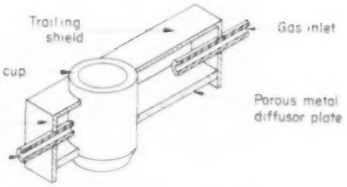


Fig. 4b Trailing and leading shield

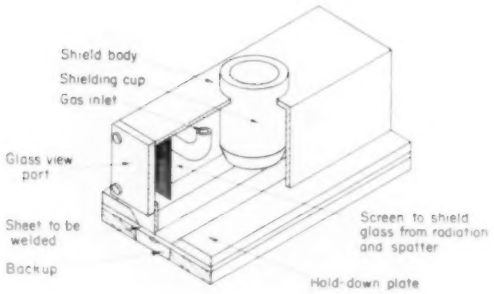


Fig. 4c Dragging shield

mum shielding with a shielding cup, use the largest available cup with the recommended gas flow and hold the nozzle-to-work distance to a minimum. The data published by manufacturers have been computed for conventional metals and may require changes when welding reactive metals. As an example, ductile tungsten-arc welds were made in $^1/_{16}$-in. thick molybdenum sheet using a standard $^5/_8$-in. diam gas nozzle.[5] This nozzle diameter is much larger than needed for similar welds on conventional materials such as aluminum or stainless steel.

Shielding cups are used in conjunction with all other shields which are open to the atmosphere since they provide the best shielding for the molten weld pool. Cups are also used in many of the flow-purged closed systems in which gas flow is maintained while welding.

Trailing Shields and Leading Shields

Many of the materials mentioned in this paper can be contaminated just by heating in air. With these materials, shielding must be provided for the weld metal and heat-affected zone just behind the molten pool. This can be accomplished through the use of a trailing shield. One type of trailing shield is shown in Fig. 4*b*. Shields of this type have been used with success on metals such as titanium and zirconium.[6]

Uniform gas coverage by the trailing shield illustrated is assured by the use of a porous-metal gas-diffuser plate. This plate is brazed to the underside of the shield near the bottom. A positive pressure of shielding gas is maintained within the shield body to produce a constant flow of gas. Without the diffuser plate, gas coverage of the entire area covered by shield would not be assured.

If the metal being welded reaches a temperature high enough for oxidation or absorption of gases ahead of the inert-gas shield provided by the shielding cup, the subsequent weld may become contaminated. This has been found to happen when welding molybdenum which possesses a high melting point and high thermal conductivity. The metal ahead of the shielding cup can be protected by the addition of a leading shield to the shielding cup. These shields are generally used in conjunction with a trailing shield as illustrated in Fig. 4*b*. Leading shields are constructed the same as trailing shields but do not shield as large an area.

For best results, the leading and trailing shields should have gas supplied separately from the supply for the shielding cup. Because of their larger orifices they require greater gas flows than do shielding cups.

Dragging Shields

Dragging shields are used as a substitute for a closed shielding system when it is not practical to use closed systems; for instance, when welding large structures. These shields consist of small chambers mounted in conjunction with a shielding cup as illustrated in Fig. 4*c*. The bottom of the shield is open, and the shield is constructed so that it conforms to the shape of the joint surfaces to provide adequate shielding. Small openings may be provided at the base of the unit to allow the shielding gas to flow from the shielded area. High gas flows are required to prevent back diffusion of air into the shielded area. Diffuser plates, similar to those used in leading and trailing shields, may be used to provide uniform gas flow over the area to be shielded. A shielding cup must be used to insure protection of the molten weld pool. Shields of this type have been successfully used for the welding of reactor components of Zircaloy-2.[6]

Backups

Backups have three important functions: (1) to support the molten weld metal and govern the contour of the root of the weld, (2) to protect the root of the weld from the atmosphere, and (3) to aid in chilling the weldment to the desired degree. Gas backups are generally required for welding materials which are easily contaminated by air. The types of backups to be considered in this paper are: solid metal, directed gas flow, simple gas flow, diffused gas flow, and pressurized gas backups.

The thickness of the material to be welded governs the type of backup to be used. Thin materials require a metallic backing to support the molten metal and to chill the weld to prevent excessive melting and burnthrough. Copper is generally used as the backup material. Heavier gages of material can be welded using backups which do not support the molten metal or chill the weld to a great degree. Backups should be designed to provide the desired degree of chilling for the thickness and material being welded, as well as to provide adequate shielding for the root side of the weld.

When using gas backups, the gas flow should be regulated and generally kept at relatively low levels to pre-

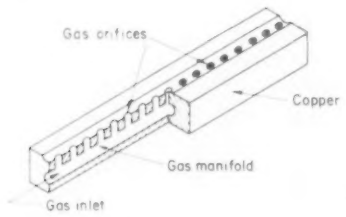


Fig. 5a Simple gas flow

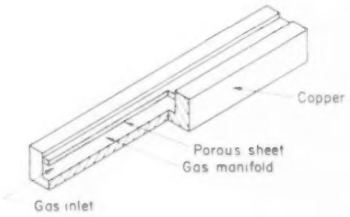


Fig. 5b Diffused gas flow

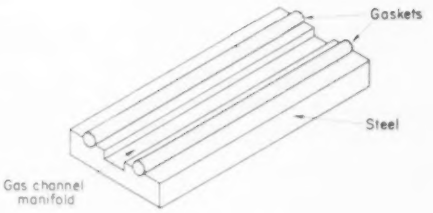


Fig. 5c Pressurized gas backup

vent interference between the backup gas and the shielding gas protecting the top of the weld. Gas flowing through the unwelded joint can interfere with the upper inert-gas shield and cause turbulence allowing entrainment of air in the shielding gas.

The simplest type of backup consists of a copper bar. This type of backup usually has a small groove located under the weld joint to allow complete weld penetration without pickup of backup material by the molten weld metal. The part being welded is clamped tightly against this backup so that little air remains at the root side of the joint. Contamination from the small amount of air in the groove beneath the joint is held to a minimum by rapid cooling of the weld to a temperature at which contamination cannot occur. Excessive heating by the arc might allow contamination of the weld by backup material; however, proper adjustment of current, arc voltage, and weld speed, and water cooling of the backup will lessen the chance of contamination from this source. Inert gas may be allowed to flow along the groove to offer some improvement in shielding at the root side of the weld.

The simplest gas backup consists of a tube or nozzle directing a stream of inert gas at the root of the molten weld pool. This type of shield sometimes contains a trailing and/or leading portion. The directed-flow type of gas backup is used for welding thick sections which do not require chilling. Directed-flow gas backups do not provide the degree of shielding provided by the other types of gas backups discussed in this section. This type of backup has been used for welding reactor components of Zircaloy-2.[7]

The gas backup shown in Fig. 5*a* is very similar to the solid-metal backups. The groove is generally slightly deeper and gas outlet holes are closely spaced along this groove. These holes are connected to a gas-supply manifold drilled through the length of the backup. A major drawback to this type of backup is the difference in gas flow at various points along the backup. Gas flow is higher near the supply end of the backup and gradually becomes lower further away from the supply end. Some backing plugs for welding thin-walled tubing are of this type. In this instance the groove is machined around the circumference of the copper plug and the gas orifices are drilled radially to join the gas-supply tube. Gas backing plugs have been used for butt welding Zircaloy-2 tubing.[8] The backup shown in Fig. 5*b* produces a more-even gas flow by maintaining a slight positive pressure below the porous-metal diffuser plate. These two types can be used with thin sheet since they also will produce a chilling effect on the weld.

The pressurized gas backup, Fig. 5*c*, is used when rapid heat transfer is not desired, but support for the molten metal is required.[9] The sheet being welded is clamped against the gasket and a slight pressure is maintained in the backup to support the molten weld metal. Good joint fitup is required to prevent excessive escape of gas through the unwelded joint. Leakage is sometimes prevented by placing tape over the joint and removing it just ahead of the progressing weld. As the weld progresses, less gas flow is required to maintain the desired pressure. If the gas flow is not decreased as the weld progresses, the flow of gas through the unwelded section of the joint will become excessive and turbulence will be introduced into the upper inert-gas shield.

Once the first pass of a multipass weld has been completed, a gas backup may not be required unless the heat from subsequent passes raises the temperature of the root pass to a temperature at which contaminators can be absorbed from the atmosphere.

Jigs and Fixtures

The welding jigs and fixtures used in inert-gas-shielded arc welding play an important role in suppressing the contamination of weldments by gaseous impurities. By providing adequate chilling of the weld metal and heat-affected zone, the weldment can be rapidly cooled below the temperature at which contamination will occur. Chilling also reduces the size of the area which will require shielding by an inert gas. However, chilling cannot be used with all materials since some materials will crack and others will have their metallurgical properties adversely affected if the chilling is too rapid.

Closed Chambers

Better protection than that afforded by the various "open" shielding devices can be obtained using closed chambers to surround the area to be welded. In closed chambers, either a static or continuous flow of shielding gas can be employed during welding. If the gas flow is maintained, it should be vented through a mercury or low-vapor-pressure oil trap to prevent back diffusion of

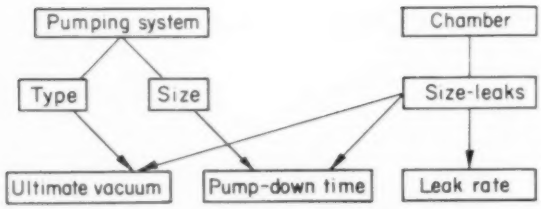


Fig. 6 Simplified relation of factors affecting vacuum-system characteristics

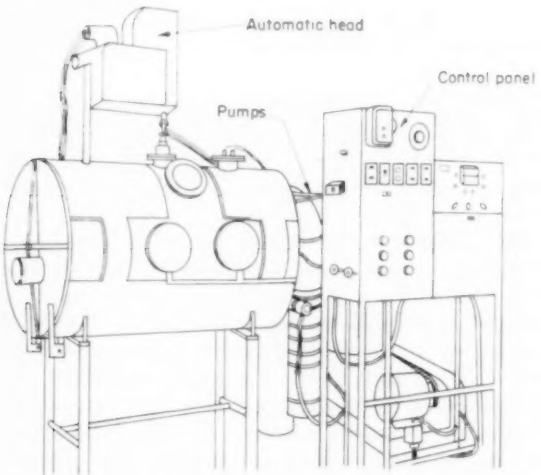


Fig. 7 General-purpose vacuum-purged chamber

air into the working chamber. The use of a static atmosphere may create very uncomfortable working conditions for manual welding. Heat will build up during any long welding job and the resulting rise in both temperature and pressure will force the operator to interrupt his work. Use of cooling jackets on the chamber can minimize this problem.

The purity of the atmosphere in a static system can be improved by the use of a gettering operation. The simplest gettering method is to melt titanium or zirconium with the welding torch before starting an important welding run. Either of these metals will absorb large quantities of oxygen and nitrogen. Gettering of a static atmosphere is probably a more reliable method of maintaining gas purity than methods involving the use of gas purification trains for the incoming gas.

Many designs of closed chambers have been used, but these can be classified into two basic types: flow purged and vacuum purged. Flow-purged chambers depend on a gas flow to remove the air contained in the chamber, while vacuum-purged chambers exhaust the air before replacing it with gas. The removal of residual impurity gases and vapor by flow purging is not so effective as a vacuum purging.

Flow-Purged Chambers

Flow-purged chambers are generally useful in welding parts which require additional shielding for protection of the heat-affected zone as well as the molten weld pool. These chambers can be further divided

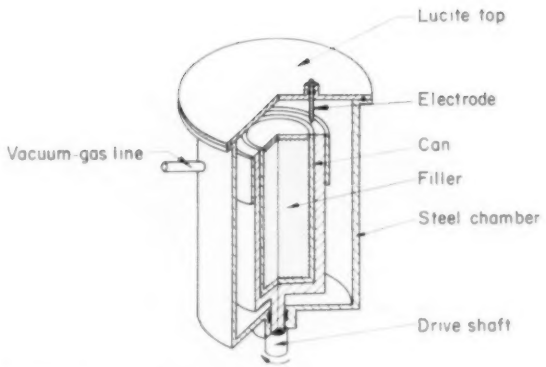


Fig. 8 Can welding chamber

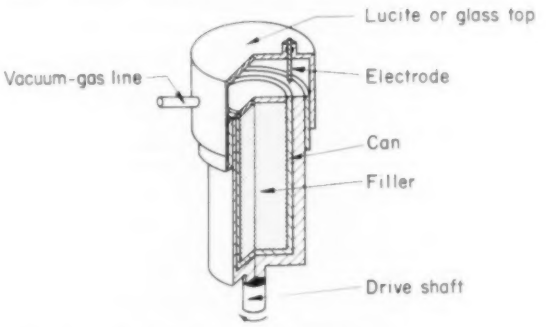


Fig. 9 Improved can welding chamber

Table 1—Theoretical Gas Composition After Purging Collapsible Chamber

Purging cycles	Ratio*	Initial gas remaining, ppm — 20	10	4
1		50,000	100,000	250,000
2		2,500	10,000	62,500
3		63	100	3,900
4		0.004	0.01	16

* Expanded volume divided by collapsed volume.

into types depending on a fixed or collapsible construction.

In the collapsible type, the initial volume of air which must be purged is kept small by collapsing the chamber to a minimum size. By alternately filling and exhausting the chamber, the percentage of air can theoretically be readily lowered to very low figures. Table 1 shows the gas purity after successive purges for chambers that can be expanded 20, 10 and 4 times their original volumes. After four purges of a chamber that can be expanded 20 times, the purity of the gas is extremely high, assuming perfect mixing and no contamination from the incoming gas or other source. At smaller ratios, more purges are required to obtain equivalent gas purity. In practice, however, such purity is seldom attained with this type of chamber since contamination from other sources increases the air retained. Either rubber or plastic must be used in collapsible chambers. Leak-tight joints in these materials are hard to obtain and some air will actually leak through them. A typical collapsible chamber is

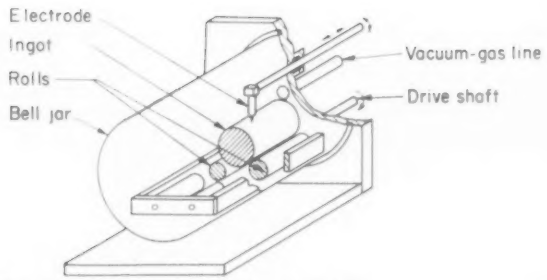


Fig. 10 Surface conditioning chamber

shown in the lead illustration, Fig. 1.† As shown in this figure, collapsible chambers are usually used for manual welding.

A fixed, flow-purged chamber depends entirely on the displacement of impurity gases by incoming shielding gas. Chambers of this type are satisfactory if the dimensions are small and they are constructed so that a steady gas stream is present to remove the impurity gas. Large chambers of this type are effective only if long purging cycles are used or if the chambers are kept full of inert gas once they are purged. In the latter case, separate access chambers are provided for moving parts in and out of the welding chamber.

Vacuum-Purged Chambers

Chambers that are evacuated before refilling with shielding gas are used to obtain the highest-purity inert atmosphere. Vacuum-purged chambers of a large variety of shapes and various degrees of atmosphere have been used extensively in the past. Reliability, consistency of atmosphere purity, and high-obtainable purity have been the main reasons for the widespread use of this type of chamber. However, at times these properties are incorrectly assumed to be characteristics of any vacuum-purged system. The advantages of vacuum-purged chambers can only be sustained by close supervision of their use by personnel familiar with (1) vacuum-system principles, (2) the various components which make up the chamber system, and (3) proper maintenance schedules for the system.

The designer and user of a vacuum-purged chamber must remember that such a system has two functions: (1) as a vacuum system and (2) as a low-pressure system. A complete discussion of vacuum-system principles is beyond the scope of this paper but the brief discussion below will highlight some of the considerations with this design.

The characteristics of vacuum systems which are of interest to the welding engineer are shown in Fig. 6. The influence of the pumping system on these characteristics is also indicated. Mechanical pumps are generally used on large systems designed for evacuation to pressures above 25 microns or small systems designed for evacuation to about 1 micron. Diffusion pumps are normally used for systems which are evacuated below 25 microns, and must be used to obtain the best evacuation. Pump down time is of importance because of economics. One method of lowering this time is to keep the chamber size as small as possible. Chambers which cover only the area to be welded can often be used to achieve this end.

As indicated in Fig. 6, both ultimate vacuum and leak rate should be considered in evaluating a chamber system. Large pumps can easily produce and maintain a low pressure in a system with a sizeable leak. Leak rate is a measure of the chamber's ability to hold a vacuum with the pumps stopped. Also of importance is the method and location of measuring the chamber pressure. Vacuum gages that depend on electrical phenomena are most generally used. Such gages are preferred to mercury gages since they indicate the total impurities present, whereas mercury gages are insensitive to condensable vapors. Several types of vacuum-purged chambers are shown in Figs. 7, 8, 9 and 10. The chamber in Fig. 7 is a general-purpose type which can be used for manual or automatic welding. The automatic arc-voltage control head on this chamber is mounted outside the enclosure and controls a remote electrode through a sliding seal. Figure 8 shows a chamber designed for welding seal welds on Zircaloy cans. Figure 9 shows how this design could be simplified, with a resulting increase in production rate because of the much smaller enclosed volume. The chamber shown in Fig. 10 is designed for remelting the sides of arc-cast ingots before forging or rolling. Welding in this chamber is started at a helium pressure of 15 in. of mercury because of the long length of weld and resulting heat and pressure buildup.

Summary

Controlled-atmosphere arc welding is becoming increasingly important to the successful welding of materials and products which, until recently, were laboratory curiosities. The choice of atmosphere shielding devices ranges from the simple shielding cups to completely enclosed chamber systems. The welding engineer must carefully consider each welding problem to determine the degree of weld shielding required to produce satisfactory weldments with the required properties. Although vacuum-purged chamber systems undoubtedly offer maximum protection and reliability, any tendency to make their use mandatory for a given material should be carefully scrutinized. Often, a carefully engineered but less sophisticated technique will be adequate.

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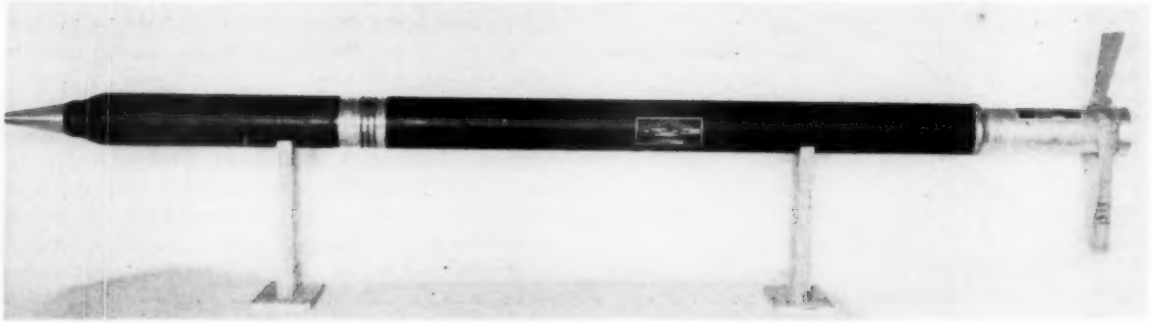


Fig. 1 LAR liquid-propelled aircraft rocket

USE OF RADIOISOTOPES IN FILLER METAL FOR NONDESTRUCTIVE INSPECTION

Study made by the authors covers the use of slightly radioactive welding wires and brazing materials as a means of nondestructive examination of uniformity and penetration in a weld with a radioactivity monitoring instrument. Metals considered are alloys of aluminum, iron and silver

BY PAUL T. BARNES AND GORDON L. LOCHER

FOREWORD. The use of radioactive welding wire is suggested primarily for fillet welds made by automatic equipment in order that the deposition of wire and radioisotope will be uniform. It is conceivable that this method of examination could also be used for manual welds wherein bead height and width would be coordinated with the examination procedure.

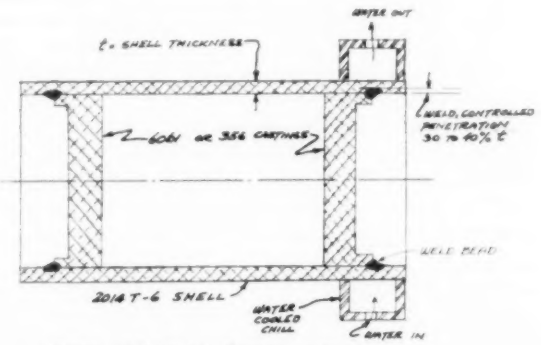
The need for this kind of inspection arose during the manufacture of the LAR liquid-propelled aircraft rocket (Fig. 1), a 5-in. high performance air-to-air rocket developed by the U. S. Naval Ordnance Test Station at China Lake, Calif. Design criteria dictated that this should be an ordnance item which could be made by small and medium-sized manufacturing plants, in event of an emergency. In line with this philosophy, the inert-gas-shielded metal-arc fusion welding method was selected as a fabrication and assembly means. The finished rocket motor contains 13 welds. Critical welds are inspected by radiography. There are two welds, however, wherein radiography alone is not sufficient. The nature of these welds is illustrated by Fig. 2.

The unit axial forces on the cylindrical shell of a pressure vessel are only half of the unit hoop forces on the shell; therefore, we are permitted to sacrifice half of the wall strength of the shell in the narrow annuli of the two circumferential welds shown in Fig. 1 without causing axial failure. Inasmuch as we are welding to a heat-treated shell of (2014 T-6) aluminum alloy, we must preserve the heat treatment of half the thickness of the shell, making no allowance for any strength remaining in the half losing the heat treatment. Controlling the loss of the heat treatment is accomplished by use of a circulating water chill over the weld area during welding; proper welding-machine settings and welding speed determine the penetration. In order to assure 50% shell strength after welding, penetration is limited to between 30 and 40% of the wall thickness. Radiography does not adequately show penetration, consequently the use of welding wire containing radioisotopes is proposed as a nondestructive method of examination.

In addition to this application for aluminum welding wire, the use of radioisotopes in steel filler wires for steel welding and activated silver for silver soldering has been covered. As a means of inspecting brazed stainless-steel sandwich joints, the use of radioactive silver appears promising.

Scope

This discussion covers a study of the use of slightly radioactive welding wire as a means of nondestructive examination of uniformity and penetration in a weld



CROSS SECTION (DIAGRAMMATIC)

Fig. 2 Cross section (diagrammatic) of rocket motor showing location of two critical welds

Paul T. Barnes is an Aeronautical Rocket Powerplant Research Engineer at the U. S. Naval Ordnance Test Station, China Lake, Calif. and **Gordon L. Locher** is a Physicist, Western Radiation Laboratory, Los Angeles, Calif.

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with a radioactivity monitoring instrument. Metals considered are alloys of aluminum, iron and silver. Aspects of the problem considered in this discussion are:

(a) Selection of suitable target nuclides for activation and subsequent measurement. The target nuclide must either be a normal constituent of the wire or an additive. The radioisotope must give a type of emission which is favorable for measurements of uniformity and penetration; it must have a half-life which is practical for the work; and it must present no health hazard.

(b) Means of introducing the additive into the wire, by alloying or electrodeposition. Metallurgical problems, compatibility and cost of the additive, and method of addition, are considered.

(c) Calculation of activities produced in the wire by neutron irradiation in thermal neutron fluxes of various strengths, for various exposure times.

(d) Means of activation, including the possibility of a local irradiation facility or irradiation in an existing AEC facility.

(e) Transportation and storage of the active wire. Examination of uniformity of activation, before use. Handling of the wire during welding.

(f) Instrumentation for monitoring the weldments and interpretation of results.

(g) Total radioactivity of weldments and the rate of decay of the activity.

Outline of Proposed Procedure

Filler wire added during welding becomes indistinguishable from the metal being welded. Radiographic, fluoroscopic, and ultrasonic testing, where applicable, show various kinds of defects in the weld, but do not show the penetration. These conventional inspection methods are sometimes not adapted to immediate use where the work is being done. Parts, work and time may be lost due to inability to make immediate checks of the welding before continuing.

In the procedure considered, radioactivity-tagged filler wire would be used. The intensity of gamma or beta radiation from a given spot of the weldment is a measure of the amount of wire added. When monitoring is done from the side opposite the weld, the intensity of radiation also becomes a measure of penetration.

Measurement of very weak radioactivity is a highly developed technology. When the radiation receiver is very close to the source, the amount of radioactivity can be so small that it is undetectable at a few feet distance, where the radiation intensity falls below background level. Use of interchangeable collimating apertures over the sensing element of the instrument allows adjustment of the area to be inspected.

Inspection can be made as soon as the work cools, by use of a portable radiation instrument. The sensing element would be a scintillation counter head on the end of cable which connects with the power supply and indicating or recording unit. This inspection would, of course, be followed by other methods when their use was indicated. And the radioactive method would be coordinated with sample weldments which were sectioned and examined by metallographic means.

Selection of Radioisotopes

In selecting suitable radioisotopes, considerable numbers have been ruled out because some property made them unsuitable or less favorable than others. The various aspects of the problem are interrelated. Elimination of one possible radioisotope may be due to unsuitability of its emission, or excessive shortness of half-life, or difficulty of alloying it with the metal of the wire, or slowness of activation in available reactors, or for some other good reason. This report only discusses methods and materials which seem practical to us.

Table 1 lists the properties of four elements considered favorable: silver and zinc as additives for aluminum wire, and iron and cobalt for steel wire. The table does not include all the radioisotopes of the elements listed, except in the case of cobalt-60. Their half-lives range from 2.3 min to 5.28 yr. All emit beta and gamma radiation of varying energies. Another silver radioisotope, Ag^{106}, has a half-life of 24 min and emits positrons of 1.5 and 1.94 Mev energy, as well as gamma rays.[1]

When neutron irradiation of an element produces radioisotopes with several half-lives, the long-lived isotope may be selected by storing the material until the short-lived ones have died down. If the half-lives show a considerable spread, measurements of the type considered here may be made while "medium-lived" activity remains. Re-examination at a later date would show the same distribution pattern at a lower intensity level.

Since aluminum acquires no appreciable activity from thermal neutron irradiation, an additive is required. Silver is favored over zinc for several reasons. The amount of silver required would not exceed 0.1 to 0.2% by weight, or 1 to 2 lb per ton of wire.

In the case of iron, the target nuclide is 0.31% of the total weight. Comparison of data for cobalt shows that a very small amount of cobalt will make an effective tagging element. Its effectiveness in this capacity is about thirty times that of the same weight of silver ($Ag^{110m;110}$). None of the alloying elements normally present in conventional steel welding wire holds any promise as a useful radioactive tagging element.

The data in columns 5, 6, 7 and 8, Table 1, are used with the arbitrarily chosen times in column 9 to compute the activities shown in column 11. The three neutron fluxes chosen are, in fact, those available in AEC irradiation facilities where wire might be activated.

The activity per gram of target nuclide is low, for short irradiation times. This is desirable, since it tends to make the health hazard negligible. Compensation for lowness of activity of source comes from use of very high sensitivity and close approach of the sensing element of the monitor. Activity of 0.1 to 0.2 microcurie (0.0001 to 0.0002 millicurie) per inch of wire is believed to be ample for this work. This is an order of magnitude suggested by practical experience in measuring low-intensity beta and gamma emissions. The effects of wall-thickness change, and variable amounts of wire used per

Table 1—Activation Production Calculations. Targets—Iron, Zinc, Cobalt and Silver

1	2	3	4	5	6	7	8	9	10	11		
										ACTIVITY "A" IN MILLICURIES PER GRAM OF PURE METAL		
RADIOISOTOPE PRODUCED	HALF LIFE	HIGH ENERGY EMISSIONS MEV	TARGET NUCLIDE	% ABUNDANCE OF TARGET NUCLIDE IN METAL	NO. OF ATOMS PER GRAM OF METAL	NO. OF ATOMS OF TARGET NUCLIDE PER GRAM OF METAL	ACTIVATION CROSS-SEC. PER ATOM OF TARGET NUCLIDE IN Cm^2 FOR THERMAL NEUTRONS = BARNS × 10^{-24}	IRRADIATION TIME t IN DAYS (EXCEPT AG 108)	SATURATION FACTOR $S = 1 - e^{-\lambda t}$	THERMAL NEUTRON FLUX 5×10^{11} PER Cm^2/SEC.	THERMAL NEUTRON FLUX 10^{12} Cm^2/SEC.	THERMAL NEUTRON FLUX 10^{9} Cm^2/SEC.
Fe^{59}	45.1 DAYS	β .271 .462 1.56 γ .191 1.098 1.289	IRON Fe^{58}	0.31%	1.08×10^{22}	3.35×10^{19}	$0.9 \pm 0.2 \times 10^{-24}$	1 7 14 21 28 45.1 ∞	.0153 .102 .194 .276 .351 .500 1.00	.0062 .041 .079 .110 .143 .203 .407	.012 .082 .158 .220 .286 .465 .814	.000012 .000082 .000158 .000220 .000286 .000406 .000814
Zn^{65}	250 DAYS	β .325 γ 1.12	ZINC Zn^{64}	48.9%	9.22×10^{21}	4.51×10^{21}	$0.5 \pm 0.1 \times 10^{-24}$	1 7 14 21 28 250 ∞	.0028 .0192 .038 .0565 .0747 .500 1.000	.0085 .059 .116 .202 .228 1.52 3.05	.017 .118 .232 .404 .456 3.04 6.10	.000017 .00118 .000232 .000404 .000456 .00304 .0061
Co^{60}	5.28 YEARS	β .306 γ 1.17 1.33	COBALT Co^{59}	100%	1.02×10^{22}	1.02×10^{22}	$20 \pm 3 \times 10^{-24}$	1 7 14 21 28 1927 ∞	.0036 .0249 .0504 .0756 .1008 .500 1.000	9.94 68.7 139. 208 278 1380 2760	19.9 137.4 278 416 556 2760 5520	.02 .137 .278 .416 .556 2.76 5.52
Ag^{110m} / Ag^{110}	270 DAYS 24.2 SECS.	β .58 2.12 2.86 γ 1.516 1.389 .935 .885 .656	SILVER Ag^{109}	48.65%	5.52×10^{21}	2.69×10^{21}	$2.8 \pm 0.5 \times 10^{-24}$	1 7 14 21 28 40 270 ∞	.0026 .018 .035 .053 .072 .0987 .500 1.000	.26 1.83 3.56 5.39 7.02 10.0 50.8 101.7	.52 3.66 7.12 10.8 14.0 20.0 101.6 203.4	.0005 .004 .007 .011 .014 .020 .101 .203
Ag^{108} *	2.3 MIN.	β 1.15 γ .43 .60 .62	SILVER Ag^{107}	51.35%	5.57×10^{21}	2.86×10^{21}	$44 \pm 9 \times 10^{-24}$	∞ (1 hr ≥ ∞) $A = 3.4 \times 10^{-9} f \phi$	1.000	1700	3400 = 3.4 CURIES	3.4 = 3400 MICRO-CURIES PER GRAM
Ag^{106} *	8.6 DAYS 24 MIN.	β^+ 1.5 γ 1.94 .511	γ .220 .409 .512 .620 .711 .815 1.04 1.24 1.55	— DATA for COLUMNS 4 TO 11 NOT AVAILABLE —								

* Ag^{108} AND Ag^{106} ARE CONSIDERED TO BE PRODUCABLE BY SMALL LOCALLY OPERABLE ACCELERATORS

inch of weld (both of which depend on the application) can be offset by changing the method of detection and indication used in the measuring instrument. The radiation detector contemplated for this work would employ a digital beta-gamma scintillation head connected to an indicating unit that shows either the average counting rates or integrates the total count on a decade scaler, at the option of the user. Intensities that vary by a factor of 5000 can readily be measured by this method.

Preparation of the Welding Wire

Aluminum

Table 2 gives pertinent data on aluminum wire containing 0.1 and 0.2% silver, by weight, for diameters of 0.020 and 0.065 in. A special melt of aluminum-silver alloy would have to be made, in order to obtain this material.[2] Addition of cobalt to aluminum would be considerably more difficult, but is considered possible. Since the percentage of silver is very low, no significant change is anticipated in the welding properties of the

Table 2—Predicted Activation of Aluminum Wire with Silver Content

Aluminum welding wire: 0.020 in. diam = 0.0508 cm diam
0.065 in. diam = 0.1651 cm diam
Density Al = 2.73 g/cc

Diameter	*Area, cm²*	*cc/cm*	*Grams per cm*	*0.1% Ag grams, Ag/cm*	*0.2% Ag grams, Ag/cm*	*0.1% Ag grams, Ag/in.*	*0.2% Ag grams, Ag/in.*
0.020 in.	0.00204	0.00204	0.00557	5.57×10^{-6}	1.11×10^{-5}	1.41×10^{-5}	2.83×10^{-5}
0.051 cm		(2.04×10^{-3})	(5.57×10^{-3})				
0.065 in.	0.0214	0.0214	0.0584	5.84×10^{-5}	1.17×10^{-4}	1.48×10^{-4}	2.97×10^{-4}
0.165 cm		(2.14×10^{-2})	(5.84×10^{-2})			$(=1.5 \times 10^{-4})$	$(=3 \times 10^{-4})$

* Exposures for Practical Activities

Wire, in.	*Thermal neutron flux*	*Exposure time, days*	*0.1% Ag initial activity in microcuries per in.*	*0.2% Ag initial activity in microcuries per in.*
0.020	10^{12}	7	0.0516	0.103
0.020	10^{11}	28	0.021	0.041
0.065	10^{12}	1	0.077	0.156
0.065	10^{11}	7	0.051	0.109

* $Ag^{110m;110}$.

Practical activity depends on type of radiation receiver and on thickness of material being welded. Illustrations chosen should give enough activity for differential rate-meter measurements with either GM or scintillation detectors, in light-walled work.

Approximate weights:
0.020 in. diam: 170 g/1000 ft
0.065 in. diam: 1780 g/1000 ft

wire or in the properties of weldments made with it.

Irradiation of Aluminum-Silver Wire

Activation of the silver consists of exposure to a flux of thermal neutrons in a nuclear reactor. There are a number of reactors operated by AEC contractors, but choice would be limited by the physical dimensions of coils of wire. The Brookhaven National Laboratory, Associated Universities, Inc., Upton, Long Island, operates a Research Reactor Facility, under contract with the Atomic Energy Commission, which has suitable irradiation tunnels. The south core hole and an instrument tunnel would accommodate coils of wire of 11-in. OD, with thermal neutron fluxes of 10^{12} and 10^{9} neutrons/cm²/sec, respectively. Either of these facilities would do satisfactory activation, with appropriate exposure times.[3]

To make use of the long-lived $Ag^{110m;110}$: after irradiation the wire would have to be allowed to "cool" until the short-lived radioactivities had fallen to a usably low intensity. This is usually done at the reactor facility. A special shipping container would have to be fabricated and passed by the Atomic Energy Commission and Bureau of Explosives, to ship the active coil in interstate commerce. An AEC License is, of course, required of the user before the material can be irradiated or used. Such license is required for the use of any radioisotope material of significant strength.

No obstacle is seen in connection with the preparation and use of aluminum-silver alloy wire for the purpose considered.

Steel

Table 1, column 11 shows that cobalt (as cobalt 60) acquires 1760 times the activity as the same weight of steel (as Fe^{59}) on exposure for two weeks. This ratio varies with exposure time because the saturation factors are different. If cobalt were added to steel to the extent of 0.05 and 0.10% and the alloy irradiated in a reactor, activities imparted to the two elements would be about equal. Since steel, alone, would acquire suitable radioactivity, there would be no point in making a special melt to add cobalt.

Two practical obstacles exist in the reactor activation of coils of steel welding wire: (1) the coils are usually larger in diameter than could be accommodated in available reactor facilities, and (2) insertion of a multilayer coil of steel wire in a reactor would result in nonuniformity of activation. The reason for (2) lies in the shielding effect, for slow neutrons, exhibited by the outer layers of wire. The inner layers would not be exposed to as high flux as the outer ones, leading to nonhomogeneity of activation.

For the reasons given above, it is suggested that a thin layer of cobalt 60 be electrolytically deposited on the steel wire, instead of generating radioactivity in the wire by exposure to neutrons. This is not a difficult process, especially if the wire is copper-clad.

Since nickel and cobalt salts form a compatible plating bath, radioactive cobalt can be applied in that way. To prevent abrasion of any radioactive material, a covering of pure nickel would be applied over the nickel cobalt 60. A series of tanks could be used to apply the coatings automatically: (1) cyanide-copper striking bath, (2) rinse; (3) cobalt 60 + nickel bath; (4) rinse; (5) nickel bath; (6) rinse; (7) wiper; (8) take-up reel. A high degree of uniformity of activation per unit length could be obtained by monitoring the plated wire and use of the monitor for automatic control of plating current, through a servomechanism. Activity per inch of wire would be of the order of 0.1 to 0.2 micro-curie.

In the case of stainless steel, a pickle bath (hydrochloric acid and rinse) would have to be used, followed by a copper-cladding bath, before application of cobalt 60 + nickel. Great care would be required to assure no flaking of the coating.

Steel or stainless-steel wires, without flux coating, could be exposed in a reactor or plated with cobalt 60. For reactor activation, the wires should be mounted in a special rack made of 2S aluminum. This rack would present a flat parallel array of wires, so the neutron flux on them would be uniform. But the weight of iron exposed at one time could not be great.

Radioactive Silver-Brazing Alloys

Activation can be calculated for most silver-brazing alloys by use of the data in Table 1 and the composition of the alloy. If the alloy contains cadmium, however, activation will be less than calculated. Cadmium strongly absorbs thermal neutrons, without producing a radioisotope.

Table 3—Absorption of Gamma Emissions in Aluminum and Steel*

	Absorber			
	Aluminum		Steel	
Radioisotope, half-life, and gamma energy†	*Thickness, in.*	*% Absorption*	*Thickness, in.*	*% Absorption*
Ag^{108}	0.040	2.4	0.040	6.8
2.3 min	0.080	4.7	0.080	13.1
0.43 Mev	0.120	7.0	0.120	19.0
	0.160	9.2	0.160	24.4
	0.200	11.4	0.200	29.5
	0.400	21.4	0.400	50.3
Ag^{108}	0.040	2.1	0.040	5.8
2.3 min	0.080	4.2	0.080	11.3
0.60 Mev	0.120	6.2	0.120	16.5
	0.160	8.1	0.160	21.3
	0.200	10.1	0.200	25.9
	0.400	19.1	0.400	45.1
$Ag^{110m; 110}$	0.080	3.4	0.080	9.3
270 days	0.160	6.6	0.160	17.7
0.935 Mev	0.240	9.8	0.240	25.1
	0.320	12.8	0.320	32.2
	0.400	15.8	0.400	38.5
$Ag^{110m; 110}$	0.080	2.7		
270 days	0.160	5.3		
1.516 Mev	0.240	7.8		
	0.320	10.2		
	0.400	12.6		
			Co^{60} 0.040	4.1
			5.28 yr 0.080	8.0
			1.25 Mev 0.120	11.8
			0.160	15.4
			0.200	18.8
			0.400	34.1
			1.00	64.0

* Calculated from narrow-beam attenuation data in NBS Circular 538.

† These are only representative sample lines of silver radioisotopes listed in Table 1.

Table 4—Beta Ranges in Aluminum and Steel: Silver and Cobalt Radioisotopes*

Source	*Energy, Mev*	*Range in aluminum, in.*	*Range in steel, in.*
$Ag^{110m; 110}$	0.53	0.025	0.008
$Ag^{110m; 110}$	2.12	0.145	0.051
$Ag^{110m; 110}$	2.86	0.204	0.075
Ag^{108}	1.15	0.072	0.022
Co^{60}	0.306	0.010	0.004

* These are only representative sample betas of silver radioisotopes listed in Table 1. Positrons from Ag^{106} (1.5 and 1.94 Mev) are within the energy range encompassed.

Irradiation with Other Neutron Sources

Use of a local neutron source for activation of silver-bearing alloys would be practical in many applications. The advantage of a local source lies in reduction of transportation time between irradiation and application. The two short-lived radioisotopes, Ag^{108} and Ag^{106}, could then be used. Since these decay rapidly, the radiation hazard is eliminated from finished work, and the test procedure is speeded.

Portable antimony^{124}-beryllium sources producing unmoderated neutron fluxes of 8×10^7 per sec (total emission) are produced by the AEC. But reduction of the initial energies to the thermal range, where they produce activation, would reduce the flux density too greatly to suffice for this application, even when digital counting is used in the detecting equipment.

A very high-voltage linear accelerator seems entirely practical for activation of short-lived radioisotopes. Silver activities of 200 to 300 millicuries per gram of silver are produced by a linear accelerator of the Applied Radiation Corp., Walnut Creek, Calif. The thermal neutron flux reaches 2×10^{11} n/cm^2/sec, which is comparable with that from large nuclear reactors. Saturation activity is obtained in an hour of irradiation. The silver activities produced are Ag^{108} (2.3 min) and Ag^{106} (24 min). Both of these isotopes are excellent tracing elements.

Irradiation of parts welded or brazed with silver-bearing alloys could be effected *after* the welding or brazing was finished. Since the activation cross section of the short-lived radioisotopes is very large compared with those of the metals being joined, post-welding activation would be preferable to pre-activation of the wire, in many instances. Re-activation could be done many times on the same piece, if necessary.

Handling and Testing Radioactive Wire

The amounts of radioactivity which we are considering are only of the order of 0.5 to 1.2 millicuries per 1000 ft of wire. This material is incorporated in, or bonded to, the wire. Its radiation is in part removed by absorption in the wire itself. Nevertheless, all regulations pertaining to use of radioactive material of the type and amount involved, and all applicable safety precautions must be observed.

Shipping containers must conform to ICC Specification 55. Approved shipping containers will serve as locked and labeled storage containers.

The monitor used to inspect weldments should have a certified radioactivity standard as an accessory, and would serve as a health-physics monitor and hand-contamination monitor, as well. Scrap wire would be preserved for disposal as radioactive waste.

Rubber or leather gloves would be worn by operators who handle the wire, and simple carrying tongs would

be provided for carrying and loading coils on reels. Film badges or pocket dosimeters would be worn by personnel working with the wire. Badges are less sensitive than dosimeters, but their record is permanent.

At some time between irradiation and use, the wire should be monitored for uniformity of activation. This can be done by running the wire between two reels, with the scintillation head of the monitor mounted over the wire as it runs through roller guides. This operation would be done before the wire was moved to the site of use.

Detection of Radioactive Weldments at a Distance

Any radioactive source ceases to be detectable when the intensity of radiation from it is less than the background radiation from universally distributed radioactivity and cosmic rays. The background intensity at sea level is about 0.02 mr/hr. So we may take an intensity 0.01 mr/hr as the lower limit of detectable intensity from a radioactive source. At points above sea level, the background rises (to about double, at 10,000 ft), so a given radioactive source is harder to detect at high elevations than at low ones.

The emission constant of cobalt 60 is 1.35 mr/hr per millicurie at 1.0 m distance. For silver-110-m it is 1.4 mr/hr/mc at 1.0 m.

If weldments in a piece of work carried 100 ft of wire at 1 mc/1000 ft, the source would be 0.1 mc. At 1 m, the intensity is 0.14 mr/hr, at 3 m it is about 0.014 mr/hr. So at 4 m or 13 ft, the intensity would be one-half the sea-level background.

Radioactive Emissions Available

The radioisotopes listed in Table 1 emit both beta and gamma radiation. In addition, the 24-min Ag^{111} emits positive electrons (positrons) of 1.5 and 1.94 Mev energy and also 0.511 Mev gamma radiation emitted when the positrons go out of existence.

Table 3 shows the absorption properties of representative gamma-ray lines from silver and cobalt radioisotopes in aluminum and steel. It is evident that the lower the gamma energy, the more rapid the absorption. Effectiveness of the proposed method of inspection is best for low-energy gamma emitters.

In the case of inspection by use of beta emitters, the reverse situation is true: the higher the beta energy, the thicker the section to which the method may be applied. Table 4 gives the approximate ranges in aluminum and steel of representative samples of beta emission from silver and cobalt radioisotopes.

Because of the low-energy of the cobalt betas, their usefulness is limited to very thin material. But the radiosilver betas provide a means of inspecting a wide range of sections, for penetration of welding rod or brazing alloy. It should be noted that the "range" applies to the distance (through metal) to the active material, not to the total thickness of the section—which may be 30 to 40% greater than this.

A third type of radiation, distinguished by its origin and energy spectrum, is available and applicable to the method proposed. This is bremsstrahlung ("brake-radiation") produced when beta particles strike matter This is X-radiation (or gamma-radiation with low energies predominating); hence it is effective for examining thin sections. Since the silver radioisotopes are copious beta emitters, a good yield of bremsstrahlung results. Its range application lies between that of the slowly absorbed hard gammas and the rapidly absorbed betas So there is excellent use for it as an inspection tool.

Instrumentation for Monitoring Weldments

A single instrument can be used for all monitoring in the proposed work, including: monitoring the wire for uniformity of activation, monitoring for possible radioactive contamination, and measuring beta and gamma intensities in the work.

The unit would comprise the following sections:

(1) A scintillation counter head connected to the amplifier unit by a flexible cable. The scintillation head would use a sodium-iodide crystal ($\frac{1}{4}$ to $\frac{1}{2}$ in. thick) fitted with a beta window (0.001-in. aluminum foil, or beryllium foil) and a lead or tungsten-alloy shield plus collimator for the incident radiation. The preamplifier and pulse-height discriminator would be integral with the head. A water jacket would be provided, to cool the multiplier tube and crystal if the ambient temperature exceeds 100° F. To conserve space, the preamplifier would employ silicon transistors, and show essentially flat frequency response from 10 to 100,000 cps.

(2) Amplifier unit. Contains the remainder of the pulse amplifier, including multivibrator and output network.

Two methods of showing output would be used: (a) ratemeter and (b) digital scaler. The former would serve for rapid indication of counting rates when the measured intensity was high. The digital scaler, with perhaps 7 decades, would be used when lower intensities are to be measured and when higher accuracy is required. An interval timer would be incorporated with the scaler.

With the development of cold-cathode decade counter tubes capable of counting 100,000 cps, it is practical to operate a decade scaler in portable form, using self-contained batteries, if desired.

By use of digital scaling, the accuracy of measurement and the lower limit of measurable intensity can be extended to limits set by: variations in the background intensity, and stability of the electronic circuits. These benefits are obtained by increasing the observation time.

References and Acknowledgments

1. Data used in this report are taken from: Oak Ridge National Laboratory Catalog of Radioisotopes, Brookhaven National Laboratory Research Reactor Facility Book, and "American Institute of Physics Handbook" (Section 8), 1957. Published by McGraw-Hill Book Co., Inc., New York, N. Y.

2. We are indebted to Mr. J. A. Wock, Jr., Assistant Chief, Physical Metallurgy Division, Alcoa Research Laboratories of the Aluminum Company of America, and to Mr. Carson L. Brooks, Metallurgical Research Laboratories of Reynolds Metals Co., for advising that it is possible and practical to make these alloys, since silver is highly soluble in aluminum.

3. We are indebted to Mr. Paul Colemann, Isotopes and Special Material Group, Brookhaven National Laboratory, for valuable advice on this subject.

This large press makes good use of diagonal bracing

A SIMPLIFIED APPROACH TO CALCULATING DESIGN STRESSES

Design methods for creating efficient machine weldments are described and discussed by the author

BY OMER W. BLODGETT

This paper will present new, simplified design methods for creating efficient machine weldments. These methods have been developed over the past few years in working with designers to help them face the question of how to design for welding. To speed this work, by reducing the amount of time and effort to a minimum, the standard design formulas applied to designing a weldment were made into nomographs, charts and tables for quick, accurate use. This paper will summarize the more important techniques that have been developed.

At one time, the easiest approach to designing for welding appeared to be that of designing empirically from past experience. This is easy, but, unfortunately, the rule thumb selection of configuration and section almost invariably results in machine members that "look heavy enough," but actually are too heavy. This means higher material costs, higher fabricating costs and more welding than is necessary.

Fortunately, this approach is gradually being dis-

Omer W. Blodgett is a Design Consultant for the Lincoln Electric Co., Cleveland 17, Ohio.

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carded and the trend today appears to be towards machine designs with a guaranteed maximum deflection based on calculations. New methods of determining forces and their effects allow designers to determine sections according to these calculations, where previously the actual load values were indeterminate. This approach makes for more efficient designs and more efficient use of the excellent properties of steel. The methods presented here will help in this approach by simplifying complicated stress analysis and the complicated, time-consuming design formulas that must be used.

Design Formulas

All design formulas cover three factors: (*a*) load, (*b*) member, (*c*) stress and strain. These three all have a relationship with each other in any given formula, depending upon the type of load. If two of these three terms are known, the third term may be found. Therefore, all problems of design will be one of the following three: (1) to find the resulting internal stress or strain caused by an external load upon a given member, (2) to find the external load which may be placed upon a given member for any allowable stress or strain, and (3) to select a certain member to carry a given load with a given allowable stress or strain.

A member is useful only when it carries a load. The *load* (force) *stresses* the member, which results in a *strain* measured as elongation, contraction, deflection or angular twist. Therefore, every member must be designed within a certain allowable load (stress) and within a certain allowable deformation (strain).

In designing within these allowables, the designer must select the most efficient *material* and the most efficient *section* size and shape. The combined properties of the material and the properties of the section determine the ability of a member to carry a load.

Load. The given information about the load is not complete unless the type, method of application, and value are fully known.

1. Type
   - (*a*) tension
   - (*b*) compression
   - (*c*) bending
   - (*d*) torsion
2. Application
   - (*a*) steady
   - (*b*) repeated
   - (*c*) impact
3. Value
   - (*a*) force, pounds
   - (*b*) moment, inch-pounds
   - (*c*) torque, inch-pounds

Here are some methods by which a value for the load may be found.

1. From motor horsepower and speed, determine torque (inch-pounds).
2. Tool pressure and diameter of tool result in torque (inch-pounds).
3. Calculate force placed on member (pounds) by dead weight of machine parts.
4. Controlling force in designing machines, such as a lift truck, may be assumed to be the maximum load required to tip machine over.
5. Maximum strength of some part, such as a cable on hoist, etc., (pounds), may be used as starting point.
6. Use the maximum force to shear pin, etc. (pounds)
7. Design for an assumed load (pounds).

Member. The necessary information about the member is not complete unless the property of the material, as well as the corresponding property of the section of the member are known.

1. *Property of Material.* The material used in the member has certain physical properties. Allowable loads are determined by applying certain factors of safety to the ultimate strengths, or, in some cases, the yield strengths of the material. These values are used in all strength problems. The modulus of elasticity is used in all deflection problems.

   - (*a*) S_t allowable tensile strength.
   - (*b*) S_c allowable compressive strength.
   - (*c*) S_s allowable shear strength.
   - (*d*) E_t modulus of elasticity, tension.
   - (*e*) E_s modulus of elasticity, shear.

2. *Property of Section.* The properties of the section of the member are the only measurement of the ability of the member to perform its task. It is necessary, and, in the long run, simpler if these properties and how to apply them are understood.

   - (*a*) A area.
   - (*b*) Z section modulus, strength factor as a beam.
   - (*c*) I moment of inertia, stiffness factor as a beam.
   - (*d*) R torsional resistance.

The performance of a member, with a given section, of a given material is measured by the product of the two properties described above.

Strength	*Deflection*
$S_t \times A$ (tension)	$E_t \times A$ (tension or compression)
$S_c \times A$ (compression)	
$S_s \times A$ (shear)	$E_s \times A$ (shear)
$S_t \times Z$ (bending)	$E_t \times I$ (bending)
$S_c \times Z$ (bending)	$E_s \times R$ (torsion)

Notice that the ability of a member to resist deflection in bending is measured by the product of its modulus of elasticity (E_t) and its moment of inertia (I). All steels have the same modulus of elasticity (E_t); therefore, it is quickly seen that a high-strength alloy steel will not improve the stiffness of a member.

Stress or Strain

Stress or strain are given in the following terms.

1. Stress
   - (*a*) S_t tensile stress.
   - (*b*) S_c compressive stress.
   - (*c*) S_s shear stress.

2. Strain is a unit movement (inches per inch in length) which is usually expressed as an over-all movement as follows:
   (*a*) e elongation, tension or compression.
   (*b*) Δ deflection, bending.
   (*c*) θ angular twist, torsion.

To what extent a resulting design is efficient depends upon how the problem is approached.

For example, the brake of an automobile stops the wheel from rotating and causes the auto to come to rest. However, this analysis of the problem does not give any indication of the requirements of the brake and the resulting design, if satisfactory, would be overdesigned.

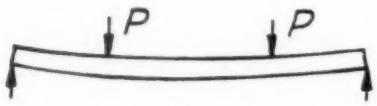

Fig. 1 Simple beam with a maximum number of forces of two

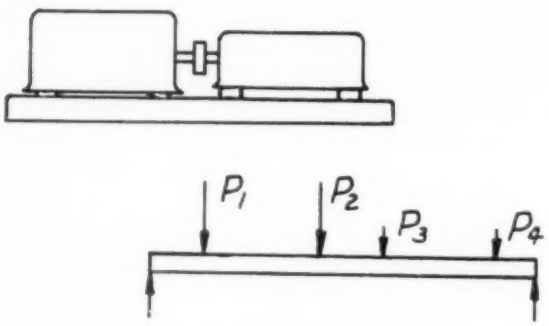

Fig. 2 Most bases have more than two loads. This figure shows an example of the simple base with at least four concentrated loads

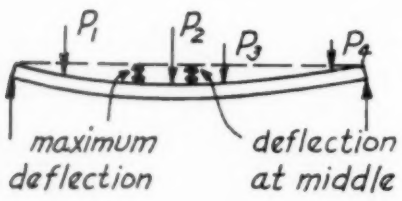

Fig. 3 Calculations may be greatly simplified and the study narrowed down to the deflection at midspan

The proper approach to this problem would be to realize that the brake is absorbing the kinetic energy of the moving auto and, when all of this energy has been absorbed, the auto will come to rest. In other words, when the energy absorbed by the brake just equals the energy of the moving auto, the auto will come to rest. With this method of approach, the engineer will design the brake to absorb a given amount of energy, in a given length of time, without overheating, etc. He has something definite to base his design upon and it will result in a very efficient unit.

A fabricator might wish to put a steel member between two heavy sections to keep them apart. His approach to this problem may be that, as long as the steel member does not buckle or drop out, the two heavy sections will be held in alignment.

A more efficient approach would be to realize that the steel member is stressed by the heavy sections (otherwise there would be no need for the steel member). These internal stresses result in a corresponding amount of strain (unit elongation or deformation). The effect of all of the strains is an over-all deformation of the member and a resulting movement of the heavy sections. The engineer determines the maximum movement of the sections which may be tolerated and designs the steel member on this basis.

Designing a Base to Resist Bending

Normally, the calculation of the maximum deflection of members subjected to bending loads is very complex. The point of maximum deflection must first be found; then, from this, the maximum deflection is found. Unless there are no more than two loads of equal value and equidistant from the ends of the base, existing beam tables in handbooks do not cover this problem (Fig. 1).

Most bases have more than two loads (Fig. 2). The maximum deflection usually does not occur at the middle of the base (Fig. 3). Two things can be done to simplify this problem. First, consider only the deflection at the middle of the member, rather than the maximum deflection at some point which is difficult to determine. This is justified, since the deflection at midpoint is almost as great as the maximum deflection, the greatest deviation coming within a few percent of this value. Second, a simple method of adding the required moments of inertia required for each individual load can be used.

For a given size member (I) (Fig. 4), it is found that each load, taken one at a time, will cause a certain amount of deflection at the middle. The total deflection at the middle would be equal to the sum of these individual deflections caused by each load.

This principle of adding deflections may be used in a reverse manner to find the required section of the member (I). For a given allowable deflection (Δ) at the middle, each individual load, taken one at a time, will require the member to have a certain section (I_1) (Fig. 5).

The required section of the beam (I) to support all of the vertical loads within the allowable vertical deflection

(Δ) will be equal to the sum of the moments of inertia (I_1) required for each load.

Any torque or couple applied horizontal to the base will cause it to deflect vertically. This can be handled in the same manner. The required moments of inertia of the member (I_1) from each torque acting separately is found and added into the total requirement for the property of the section (I).

The following two formulas may be used to find the individual properties of the section (I_1) (or a shorter method would be to make use of the nomograph in Fig. 6).

For each force

$$I_1 = \frac{F_1 L^2}{48E} \frac{(\Delta)}{(L)} (3K_1 - 4K_1^3)$$

For each couple

$$I_1 = \frac{C_1 L}{16E} \frac{(\Delta)}{(L)} (4K_1^2 - 1)$$

For more accurate values, the two formulas have been simplified into the formulas given below in which the expression $\left(K_1 = \frac{a_1}{L}\right)$ now produces a constant which

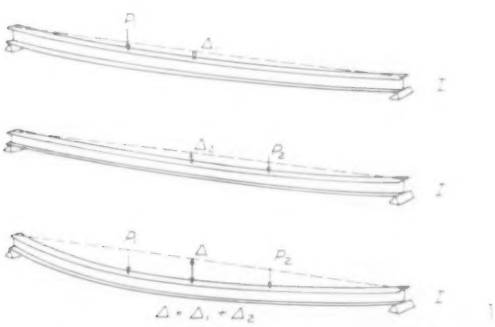

Fig. 4 Method of finding the resultant deflection for each individual force applied to a beam and how these deflections may be added to give the total deflection and center or midpoint

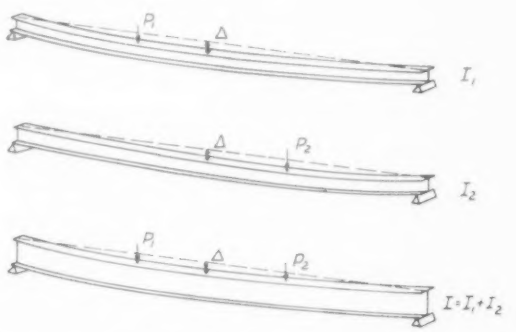

Fig. 5 An allowable deflection for a beam with a particular individual force may be converted into resultant moment of inertia. The resultant moments of inertia may be totaled to give the final value for a member with several applied forces to it

Required moment of inertia for each load. Total these values
load P
moment M
Problem: Base 60" long with several loads.
Find: required moment of inertia I
Loads P 450 lbs located 9" from end
Pivot line
Pivot line
Unit deflection at center inches per inch
load (lbs)
moment (in lbs)
length base (in)
distance of load from end
ratio
required moment of inertia (for each load P or moment M)
Use this nomograph to find I for each value of P or M, add these values to get total required moment of inertia of base I
This assumes no weight of beam and is good for steel only

Fig. 6 Nomograph to find the individual moments of inertia for each applied load or couple on a base. The moments of inertia are then totaled to give the resultant moment of inertia required for the base

Table 1

K	A_1	B_1	K	A_1	B_2	K	A_1	B_1
0	0	2.083×10^{-9}	0.17	3.405×10^{-10}	1.842×10^{-9}	0.34	5.002×10^{-10}	1.120×10^{-9}
0.01	0.2083×10^{-10}	2.083	0.18	3.588	1.813	0.35	6.101	1.063
0.02	0.4166	2.080	0.19	3.768	1.783	0.36	6.204	1.003
0.03	0.6243	2.076	0.20	3.944	1.750	0.37	6.301	0.9425
0.04	0.8312	2.070	0.21	4.118	1.715	0.38	6.392	0.8900
0.05	1.038	2.063	0.22	4.268	1.680	0.39	6.477	0.8158
0.06	1.244	2.053	0.23	4.453	1.642	0.40	6.556	0.7500
0.07	1.449	2.043	0.24	4.616	1.603	0.41	6.627	0.6825
0.08	1.653	2.030	0.25	4.774	1.563	0.42	6.692	0.6133
0.09	1.855	2.016	0.26	4.928	1.520	0.43	6.750	0.5425
0.10	2.056	2.000	0.27	5.079	1.476	0.44	6.801	0.4700
0.11	2.355	1.983	0.28	5.224	1.430	0.45	6.844	0.3958
0.12	2.452	1.963	0.29	5.364	1.381	0.46	6.880	0.3221
0.13	2.647	1.942	0.30	5.500	1.333	0.47	6.898	0.2425
0.14	2.847	1.920	0.31	5.631	1.282	0.48	6.928	0.1633
0.15	3.031	1.896	0.32	5.756	1.209	0.49	6.940	0.0825
0.16	3.219	1.870	0.33	5.876	1.176	0.50	7.000	0

Couple C is positive if it causes beam to deflect downward.

is found in Table 1:

$$I_1 = \frac{P_1 L^2 A_1}{\frac{(\Delta)}{(L)}} \qquad I_1 = \frac{C_1 L B_1}{\frac{(\Delta)}{(L)}}$$

(Force P_1) (Couple C_1)

When a force is applied to the member, use the constant (A) and substitute into the first formula. When a couple is applied to the member, use the constant (B) and substitute into the second formula.

Designing a Base to Resist Twisting

A motor drive mounted on a base tends to twist the base. While a good foundation supports bending loads, it contributes little in preventing the base from twisting. Other steps, therefore, must be taken in order to build in proper resistance to twisting.

The torsional resistance of a frame or base is approximately equal to the sum of the torsional resistances of its individual parts.

For this reason, it is important to use sections having high torsional resistances and equally as important to be able to evaluate these torsional properties with little effort.

Closed tubular sections and diagonal bracing are the best methods to resist twisting efficiently.

Solid or round tubular closed sections have ex-

Section	Shear Stress	(for steel) Rotational Resistance
d	$S = \frac{16T}{\pi d^3}$	$R = .0982\ d^4$
d_1 d_2	$S = \frac{16Td_2}{\pi(d_2^4 - d_1^4)}$	$R = .0982\ (d_2^4 - d_1^4)$
d	$S = \frac{3T}{\pi dt^2}$	$R = 1.0472\ t^3 d$
d	$S = \frac{4.8T}{b^3}$	$R = .1406\ d^4$
b, d	$S = \frac{T}{\alpha\ bd^2}$	$R = \beta\ bd^3$

$\frac{b}{d}$ =	1.00	1.50	1.75	2.00	2.50	3.00	4.00	6	8	10	∞
for solid rectangular sections α	208	231	239	.246	.258	.267	.282	.299	.307	.313	.333
β	141	196	214	.229	.249	.263	.281	.299	.307	.313	.333

Section	Shear Stress	Rotational Resistance
b, t_1, t_2, d, d_1	mid-length short side: $S = \frac{T}{2t(b-t)(d-t_1)}$; long side: $S = \frac{T}{2t_1(b-t)(d-t_1)}$	$R = \frac{2\ tt_1(b-t)^2(d-t_1)^2}{bt + dt_1 - t^2 - t_1^2}$
Use this for diagonal bracing	single brace	$R = .3543\ I$
	double brace	$R = 1.061\ I$ of diagonal brace

Table 2—Estimating the torsional resistance resulting from the use of diagonal bracing

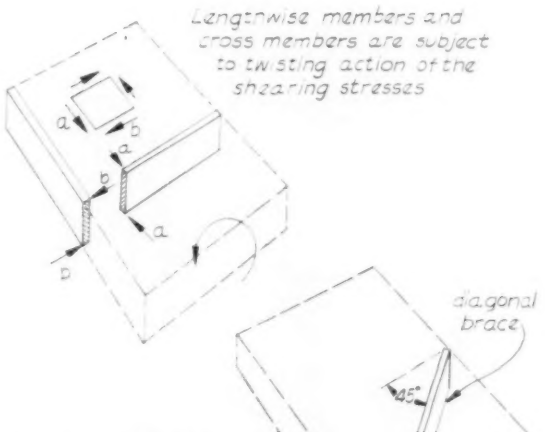
Lengthwise members and cross members are subject to twisting action of the shearing stresses
a
b
a
b
a
b
diagonal brace
45°
There is no twisting action on 45° diagonal member since shear components cancel out
Only diagonal tension and compression are formed. which place member in bending. member is very rigid.

Fig. 7 Use of diagonal members to make up a "grid section" for greater torsional resistance and lateral stability

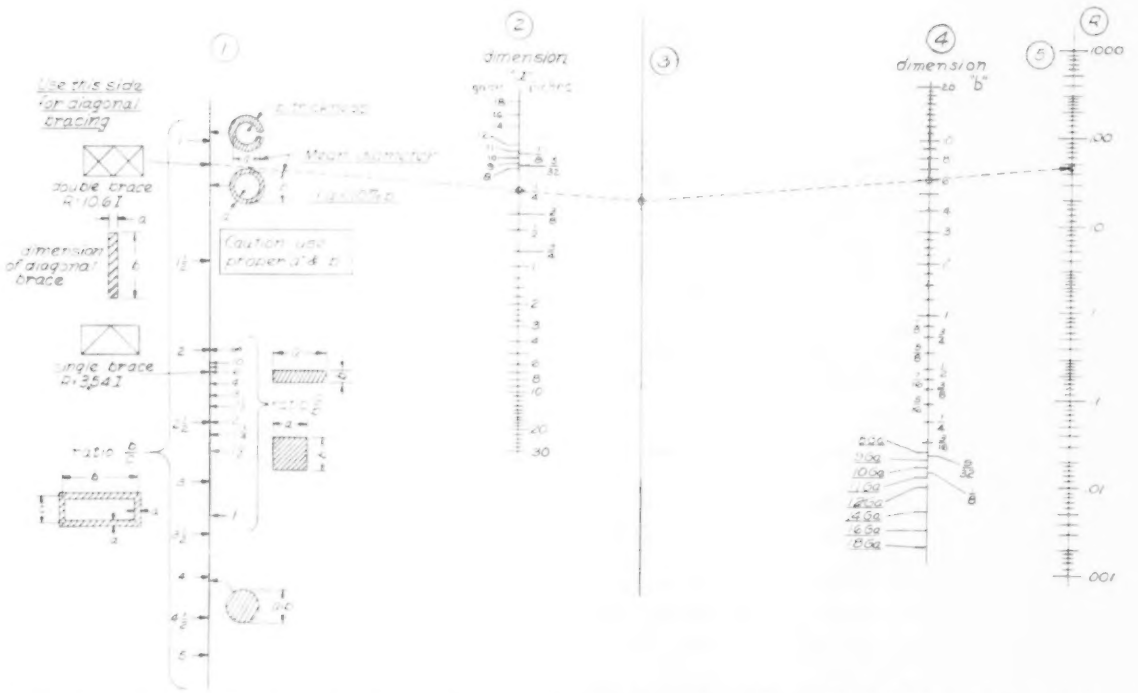

Fig. 8 Nomograph to estimate the torsional resistance of a base or frame by adding up the individual values for the part which make up the frame

ceptionally high torsional resistance because the shear stresses are uniformly distributed around the circumference of the section.

A square or rectangular closed tubular section is next best. The greatest shear stress occurs along the middle of each flat surface; the lowest shear stress occurs at the outer corners of the section. Values for the torsional resistance of these sections are given in Table 2.

By placing diagonal braces at 45 deg to the base, the shear stresses from the twisting action produce a resultant tensile and compressive force acting lengthwise on the brace. The twisting forces on the brace cancel out and the resulting combination of forces produce a bending action (Fig. 7). A properly designed diagonal brace will have high resistance to bending and will, therefore, keep the base from moving under the external twisting load. A good estimation of the torsional resistance resulting from the use of diagonal bracing is given in Table 2.

It is important that the diagonal braces have a high moment of inertia (I) in order to be rigid. It is also important that they have sufficient stiffness, so there will be no buckling under severe torsional loading of the base. Since the diagonal brace is not subjected to any twisting action, it is not necessary to use a closed box section. As the unsupported length of the diagonal brace becomes longer, it may be necessary to add a flange. This is done by flanging one edge of the brace or using an angle bar or Tee section. For open frames with no flat panel, it is better to use a channel or I-beam section having two flanges.

Open sections, such as flat bars, angles, channels and I-beams have very little torsional resistance. They are only as good as the sum of the torsional resistances of the flat areas of which they are made. The torsional resistance of a flat area is given in Table 2 and is approximately equal to:

$$R = {}^1/_3\, wt^3 \qquad w = \text{width (in.)}$$
$$t = \text{thickness (in.)}$$

It is interesting to note in the case of open sections, for a given thickness and over-all width of section, that the torsional resistance remains about the same regardless of what shape it is bent or formed into, as long as it does not become closed.

To simplify the work of finding torsional resistance, the nomograph in Fig. 8 may be used. Each individual section is run through the nomograph to find its torsional resistance (R).

Flat areas may be used by starting at the proper place on line 1 (type of section) giving the ratio of width to thickness of area.

Rectangular tubular sections may be used by starting at the proper place on line 1, giving the ratio of width to depth of the box section.

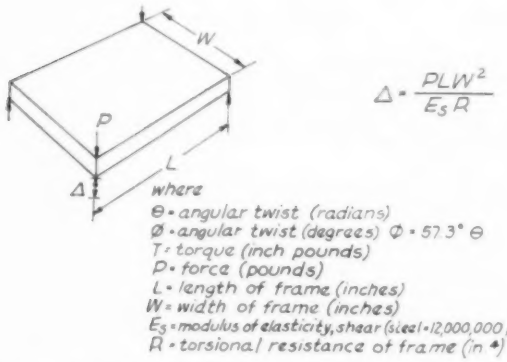
W
P
L
Δ
$\Delta = \frac{PLW^2}{E_S R}$
where
θ = angular twist (radians)
Ø = angular twist (degrees) Ø = 57.3° θ
T = torque (inch pounds)
P = force (pounds)
L = length of frame (inches)
W = width of frame (inches)
E_S = modulus of elasticity, shear (steel = 12,000,000 psi)
R = torsional resistance of frame (in⁴)

Fig. 9 Method of studying torsional resistance of a base whereby the angular rotation is converted into vertical deflection for a more accurate method of reading the results

Diagonally braced frames may be used by starting at the proper place on line l.

When this is completed, these values are added together to give the total torsional resistance (R) of the frame or base.

The total value of (R) is used in the standard torsional formula for round shafts in place of the conventional polar moment of inertia (J) and the resulting angular twist will be found:

$$\theta = \frac{TL}{E_s R}$$

For large frames or bases, it may be more convenient to replace angular twist (θ) with vertical deflection or movement of one corner of the frame when the other three corners are held (Fig. 9).

The nomograph in Fig. 10 will simplify the work of estimating the angular twist of a frame or base.

Use of Stiffeners

Frequently, the top panel of a weldment may not be thick enough to support a given load, even though the section of which it is a part has sufficient moment of inertia (I) to resist bending properly.

Rather than increase the thickness of this panel, it is usually recommended to add stiffeners or diaphragms to reduce the unsupported length of the panel (Fig. 11).

The chart in Fig. 12 shows how the thickness of a panel may be reduced by means of attaching stiffeners to the panel. The horizontal axis is the ratio of the length of the panel to its width; the vertical axis is the relative thickness of the panel with stiffeners. This chart is for panels with one stiffener to five stiffeners.

For example, the thickness of a panel having a length twice the width, $\frac{b}{a} = 2$, with a uniform load can be reduced to 73.5%, if one stiffener is added, resulting in the same deflection or equivalent stiffness. If two stiffeners are added, this thickness would be 53.4%.

The nomograph in Fig. 13 will give the required spacing of stiffeners, expressed as a ratio of the width of the panel, for any condition, of either a uniform or a concentrated load.

Stiffeners are also used to stiffen a panel, regardless of how flexible or rigid they are. These will increase the stiffness of the whole panel by increasing the moment of

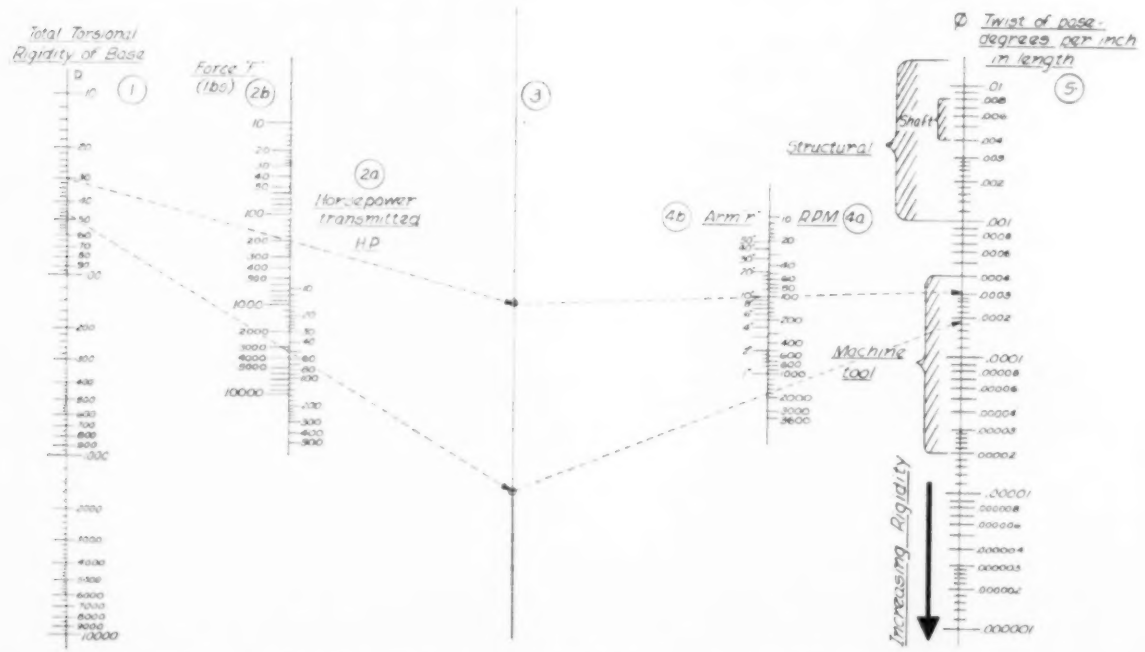

Fig. 10 Nomograph to calculate or estimate the angular twist of a base as a result of the twisting load

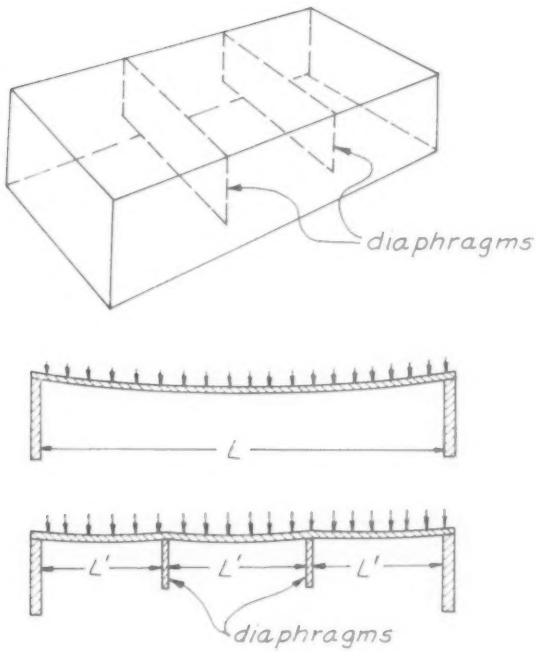

Fig. 11 Top indicates a use for stiffeners or diaphragms. Bottom illustrates the use of stiffeners or diaphragms to reduce the unsupported length of the panel and allow a thinner section to be used

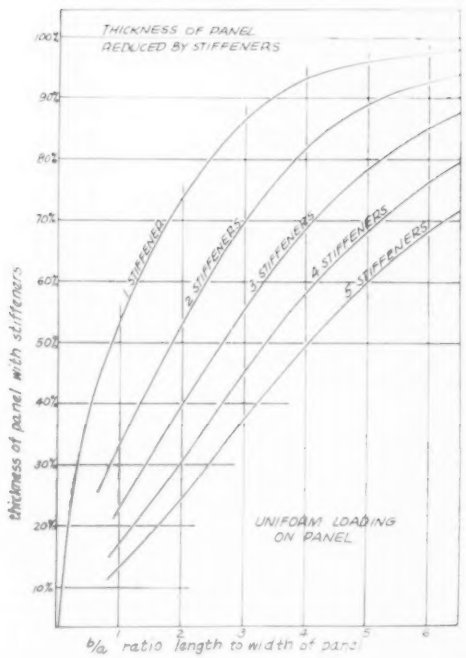

Fig. 12 This chart illustrates the reduction in thickness of a panel which may be obtained as a result of applying stiffeners to the panel and reducing the area of the unsupported panel

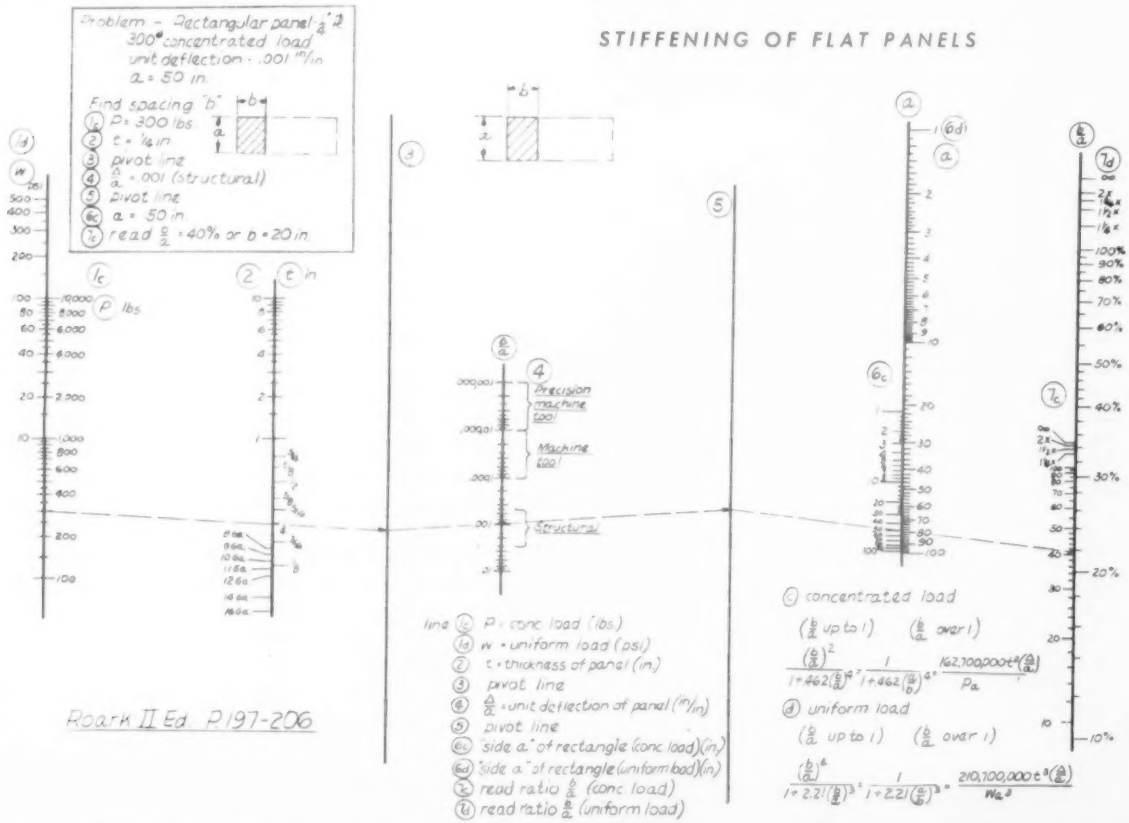
STIFFENING OF FLAT PANELS
Problem - Rectangular panel
300# concentrated load
unit deflection - .001 in/in
a = 50 in.
Find spacing "b"
P = 300 lbs.
t = 1/4 in.
pivot line
Δ/a = .001 (structural)
pivot line
a = 50 in.
read b/a = 40% or b = 20 in.
Precision machine tool
Machine tool
Structural
line (1c) P = conc. load (lbs.)
(1d) w = uniform load (psi)
(2) t = thickness of panel (in.)
(3) pivot line
(4) Δ/a = unit deflection of panel (in/in)
(5) pivot line
(6c) "side a" of rectangle (conc load) (in)
(6d) "side a" of rectangle (uniform load) (in)
(7c) read ratio b/a (conc. load)
(7d) read ratio b/a (uniform load)
c concentrated load
(b/a up to 1) (b/a over 1)
d uniform load
(b/a up to 1) (b/a over 1)
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Fig. 13 Nomograph to compute the distance between stiffeners in order to stiffen a panel within certain allowable deflections

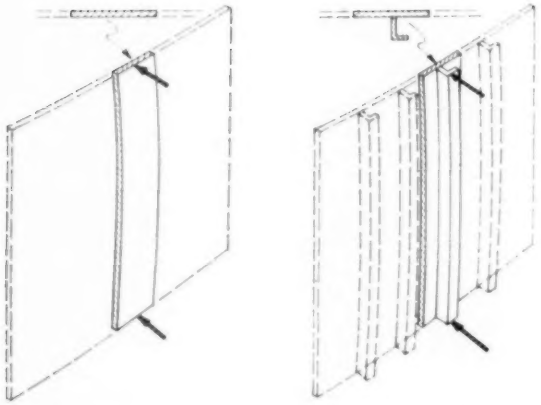


Fig. 14 Stiffeners may be added to panels to increase their stiffening effect, even though the entire unit may deflect to a certain amount

$$C_p = \frac{A_s d}{A_s + A_p} + \frac{t}{2} \qquad C_s = h - C_p$$

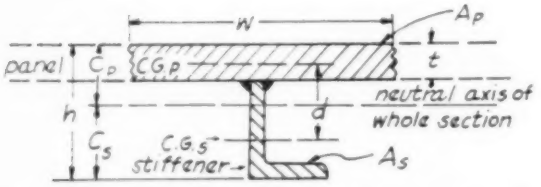


Fig. 15 Formula and how to apply it in order to obtain the resultant moment of inertia of a built-up section made up of stiffeners applied to flat plate

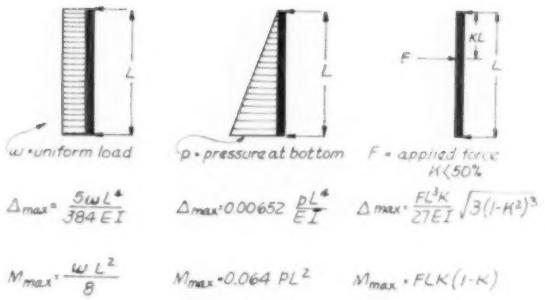


Fig. 16 Three examples of how to calculate the deflection as well as bending moment on a panel under various types of loading

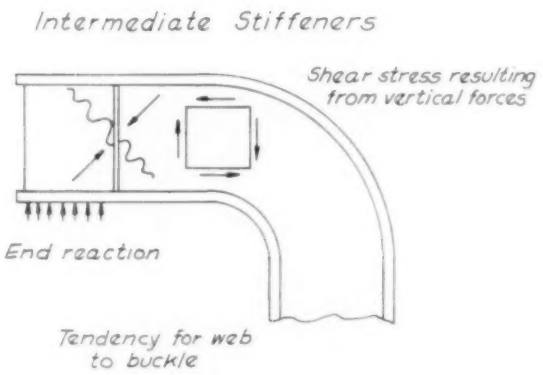


Fig. 17 Web stiffeners on just one side of the web will satisfy the requirements to resist web buckling. These stiffeners are frequently used on girders, as well as the horizontal portions of frames subjected to high shear reactions, such as presses

inertia (I) of the panel (Fig. 14).

The usual method is to consider a section of the panel having a width equal to the spacing of the stiffeners. In this manner, just one stiffener will be included in the panel section (Fig. 15). The resulting moment of inertia (I) of the stiffener and panel may be found from the following formula:

$$I = I_s + \frac{A_p t^2}{12} + \frac{A_s A_p d^2}{A_s + A_p}$$

where

W = distance between stiffeners.
*d = distance between center of gravity of panel and stiffener.
*A_s = cross-sectional area of stiffener.
A_p = cross-sectional area of panel.
t = thickness of panel.
*I_s = moment of inertia of stiffener.

The panel section may then be treated as a simply supported beam and be designed with sufficient moment of inertia to withstand whatever load is applied (Fig. 16).

The maximum stress in the outer fibers of either the panel or the stiffener may be found by using the corresponding value of (C) and the maximum moment (M_{max}) in the following formulas:

$$\text{Panel: } S_p = \frac{M_{max}\, C_p}{I} \qquad \text{Stiffener: } S_s = \frac{M_{max}\, C_s}{I}$$

The third use of stiffeners is to give proper support against buckling from diagonal compressive stresses in a section subjected to high vertical shear forces. All vertical shear stresses have an equal value of horizontal shear stress; these two stresses combine to form a diagonal compressive stress and a diagonal tensile stress. For thin, deep web sections, a high diagonal compressive stress might cause the web to buckle unless properly stiffened.

Web stiffeners on just one side of the web will satisfy the requirements to resist web buckling. These stiffeners are frequently used on girders, as well as the horizontal portions of frames subjected to high shear reactions, such as presses (Fig. 17).

Designing a Housing to Resist Gear Loads

Given in Fig. 18 are some of the basic forces on the housing from the gearing where:

* Data obtained from information in steel handbooks.

hp = horsepower transmitted.
ϕ = pressure angle, usually $14^1/_2$ or 20 deg.
D = pitch diameter of gear, inches
rpm = revolutions per minute of gear.
θ = helix angle, if helical gear.
a and b = position of gear on shaft, inches.

The vertical reaction at the bearings caused by the weight of the shaft and the gears is:

$$F_{wb} = \frac{a\,W_a + bW_b + c\,W_c}{d}$$

The vertical reaction at the bearings caused by the tangential force is:

$$F_t = \frac{126{,}000.\ \text{hp}}{D\ \text{rpm}}$$

$$F_{ta} = \frac{F_t b}{d}$$

$$F_{tb} = \frac{F_t a}{d}$$

The horizontal reaction at the bearings caused by the radial force is:

$$F_{ra} = F_{ta} \tan \phi$$
$$F_{rb} = F_{tb} \tan \phi$$

In the case of helical gears, there is a side thrust applied at the pitch circle. This produces an end thrust on the shaft. There is no end thrust from herringbone gears, since the end thrust from each half of the gear is equal and opposite in value to the other half.

$$F_e = F_t \tan \theta$$

This also produces a couple on the bearing supports.

$$F_{ea} = F_{eb} = \frac{F_e D}{2d}$$

Vertical Stiffness of Housing

The cross section of the housing must have sufficient moment of inertia (I_x) about the horizontal neutral axis to resist the bending moments of the vertical forces of the weights of the shaft and gears (F_w) and the tangential force of the gear (F_t) as well as the horizontal radial force of the gear (F_r).

Convert the horizontal radial forces into couples by multiplying these forces by their distances from their application to the neutral axis (Y) of the side member of the housing.

Treat each vertical force and couple separately and use the nomograph in Fig. 6 to find the required moment of inertia about the (X) axis, for each of the loads.

Total these values to get the required moment of inertia (I_x) for the side member of the housing.

Forces and couples are positive if they cause the side member to deflect downward under load. Positive forces and couples require positive moments of inertia (Fig. 19).

Horizontal Stiffness of Housing

If the gears are of helical type (but not herringbone), there is an end thrust on the shaft (F_e) causing a horizontal bending of the side member.

The nomograph in Fig. 6 can be used to find the in-

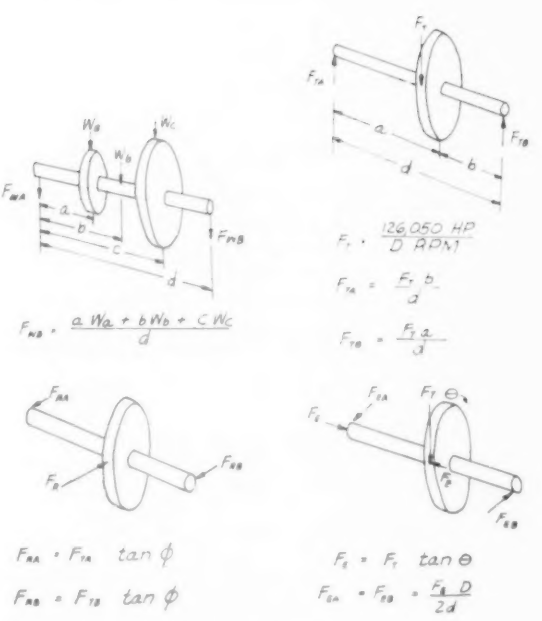
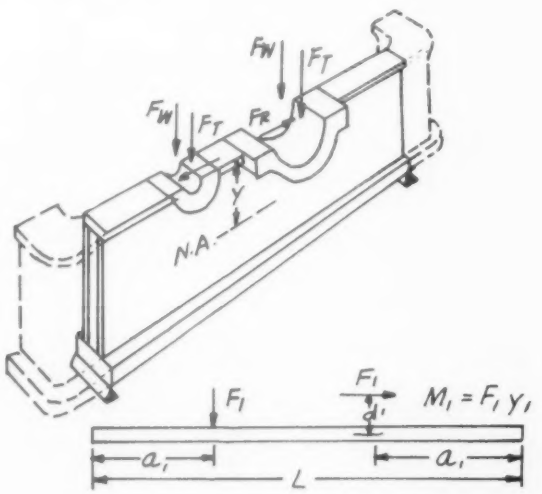

$F_{wA} = \frac{a\,W_a + bW_b + cW_c}{d}$
$F_t = \frac{126{,}050\ HP}{D\ RPM}$
$F_{ta} = \frac{F_t\,b}{d}$
$F_{tB} = \frac{F_t\,a}{d}$
$F_{AA} = F_{ra}\ \tan\phi$
$F_{AB} = F_{rB}\ \tan\phi$
$F_e = F_t\ \tan\theta$
$F_{eA} = F_{eB} = \frac{F_e\,D}{2d}$

Fig. 18 The four basic loadings on a housing from the gear train. The formulas are easy to apply and result in forces on the housing



$$I_1 = \frac{F_1 L^2 A_1}{\left(\frac{\Delta}{L}\right)}$$

$$I_1 = \frac{M_1 L B_1}{\left(\frac{\Delta}{L}\right)}$$

Fig. 19 Section on a housing may be isolated to study the vertical and horizontal forces applied to it for determining the proper moment of inertia about the horizontal axis

dividual moments of inertia about the (Y) axis, to resist these side forces. These values are totaled to give the required moment of inertia (I_y) of the side member about the vertical neutral axis (Fig. 20).

Torsional Stiffness of Housing

The end thrust of the shaft (F_e), if helical gears are used, acts at the level of the bearing and not at the horizontal neutral axis of the side member. This causes twisting of the side member and the member must have sufficient torsional resistance for this twisting action.

The torque (T) of each section of the member is the product of this end thrust (F_e) and the distance of the application of the force to the horizontal neutral axis of the member (Y).

Use the equations given in Fig. 21 to find the resultant torques in the various parts of the member and design for the maximum value.

Compressive Stiffness of Housing

The section of the housing directly below the bearing must be treated as a column and have sufficient stiffness to carry the weight of the shaft and gears (F_w), as well as the tangential force (F_t). When the side of the housing is made of a single vertical web plate, additional stiffeners or brackets may have to be used directly below the bearing for proper support.

The bearing support must have sufficient width to receive the bearing (Fig. 22).

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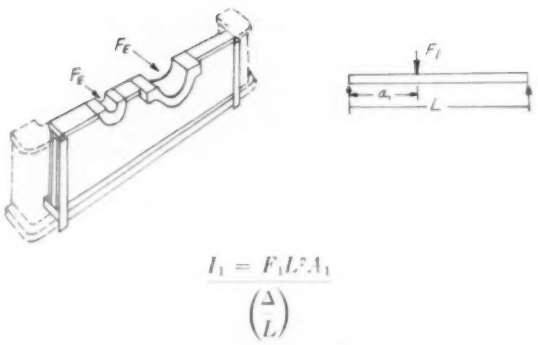

Fig. 20 Section of a housing is isolated so that the horizontal forces on it may be considered. The proper moment of inertia of the side of the section is determined from this

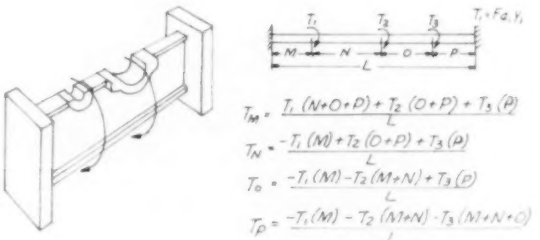

Fig. 21 Section of a housing may be isolated to study its torsional resistance

Fig. 22 Illustrates how a section of a housing may be isolated for study of the stress of compressive forces

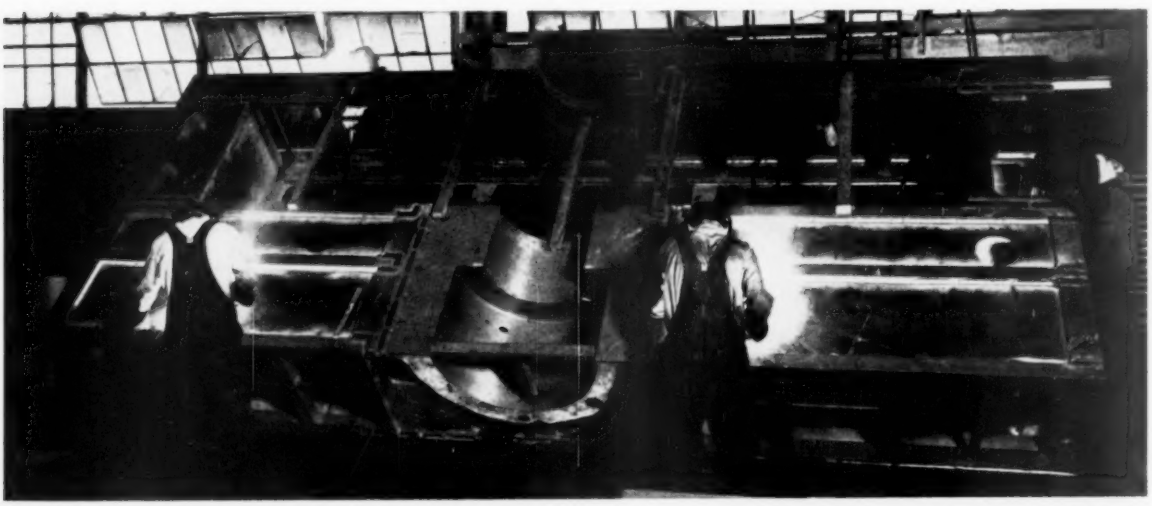

Fig. 23 Large marine base being welded. This base uses composite construction in that steel castings are used for the bearing housings

THE VALUE OF NITROGEN AS A WELD BACKING GAS

Author indicates that nitrogen backing gas may be substituted for argon gas, with little or no detrimental effect, when used on the high-nickel and stainless-steel alloys investigated

BY R. V. ANDERSON

SUMMARY. High-nickel and martensitic stainless-steel alloys are relatively insensitive to nitrogen backing-gas pickup. The austenitic stainless steel is slightly more sensitive. Nitrogen backing gas may be substituted for argon gas on the alloys tested with little or no detrimental effect. A conversion from argon to nitrogen gas represents a cost saving of approximately 90%. The work indicates that nitrogen gas may be safely introduced into the weld metal at a maximum level of one-one hundredth percent for each one percent of chromium in the base metal.

Background

Oxygen, hydrogen and nitrogen when introduced into weld metal cause brittleness, which results in decreased ductility and, in some cases, loss in ultimate strength. These gases may enter the weld metal through the destructive distillation of air caused by the arc.

Shielding of the arc from the breakdown of air is accomplished by the covering on electrodes or by the use of inert gases. Shielding is never complete, but is adequate for the physical results required. Factors limiting complete shielding are turbulence of the gas envelope and weld puddle, and the spray or droplet pattern of the filler metal.

Nitrogen forms simple nitrides with iron, and complex nitrides with other alloying elements in steel. Nitrogen has appreciable solubility in ferrite directly below the recalescense point. In alloy steels, it has affinity for columbium, vanadium, titanium, zirconium and molybdenum. Nitrogen is a strong austenitizer which can substitute for nickel. Thus a given percentage of nitrogen would have various effects on steels of different alloy compositions.

In general, small amounts of nitrogen are believed to be held in solid solution by the iron matrix and, therefore, undetectable under the microscope. In larger quantities, nitrogen is readily observed as Fe_4N nitride needles. In still higher percentages, nitrogen forms a eutectoid known as braunite made up of the nitride Fe_4N and iron containing a small amount of nitrogen in solid solution. The addition of alloying ingredients having affinity for nitrogen complicates the problems of microscopic observation. It is for these reasons that the use of argon and nitrogen as backing gases is evaluated principally on the basis of comparative physical tests.

Commonly used jet-engine materials such as AMS-5504C(410), AMS-5524B(315) and PWA-673 (Nimonic 75) contain occluded, combined and absorbed gases.

Nitrogen is one of those gases present in plate, sheet and filler wire materials. Available chemical analysis will yield the combined nitrogen, but it is doubtful that all of the occluded and adsorbed nitrogen will show in the total. Therefore, the nitrogen content given is comparative but not necessarily complete.

The tests compare an acceptable welding method, namely, argon gas for the torch and backup, with a proposed method using argon gas for the torch and nitrogen for backup.

Figure 1 shows the machine equipment used in the tests and Fig. 2 the production application.

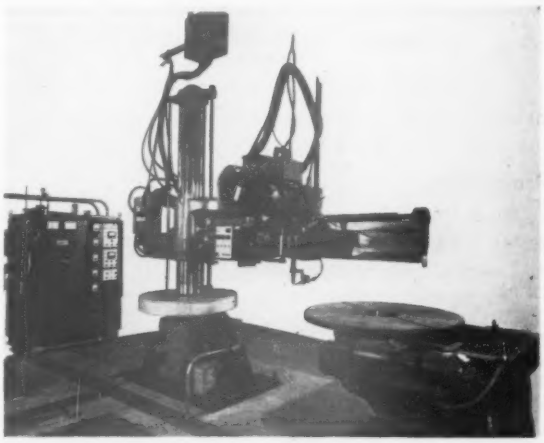

Fig. 1 Inert-arc welding equipment for missile components and research

R. V. Anderson is a Metallurgical Welding Engineer at the Standard Steel Corp., Los Angeles, Calif. and Decatur, Ill.

Test Methods

In order to achieve as accurate a comparison as possible, all test plates of a class and thickness, and filler wire of a type and size were taken from identical heats. All argon gas used was taken from one bottle. The same was true of the nitrogen gas.

The tests were evaluated by X-ray examination, tensile specimens, and face and root bends. A nitrogen analysis was made of the weld by drilling samples completely through the weld. Photomicrographs (× 40) were made for examination of the complete weld. Also, visual surveys were made at magnifications of × 100 and × 500. Micro specimens were prepared for comparative examination with Marbles etch. Time did not permit the use of the many possible etching solutions favored by individual metallographers.

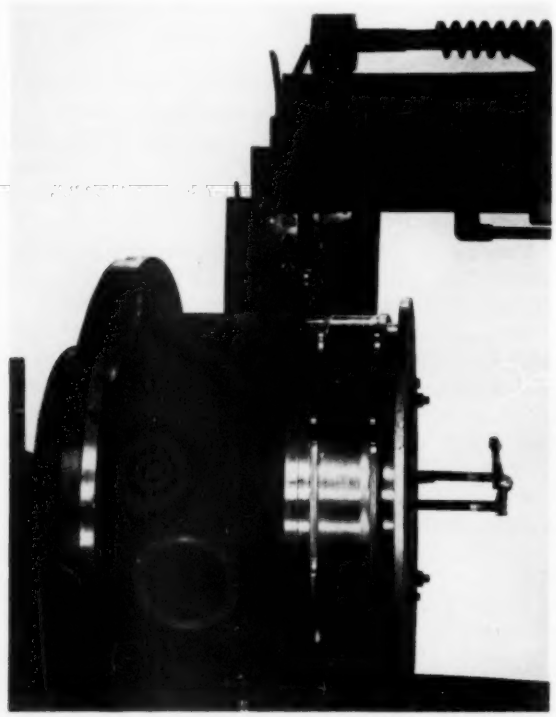

Fig. 2 Backing-gas arrangement for engine components

Procedure

Three typical production materials were used in the tests: A high-nickel alloy, a martensitic stainless steel, and an austenitic stainless steel.

The normal analysis of the plate materials used is given below:

1. PWA-673-C (Nimonic 75)

Carbon	0.08–0.15
Manganese	max–1.00
Sulfur	max–0.015
Silicon	0.30–0.80
Chromium	19.00–21.00
Titanium	0.25–0.50
Iron	max–2.00
Copper	max–0.50
Aluminum	max–0.40
Cobalt	max–1.00
Nickel = Remainder	

2. 410-AMS 5504C-SAE 51410

Carbon	0.15–max
Manganese	1.00–max
Silicon	1.00–max
Phosphorus	0.040–max
Sulfur	0.030–max
Chromium	11.50–13.50
Nickel	0.75–max
Molybdenum	0.50–max
Aluminum	0.50–max
Copper	0.50–max
Tin	0.05–max

3. 316–AMS 5524B-SAE 30316

Carbon	0.08–max
Manganese	2.00–max
Silicon	1.00–max
Phosphorus	0.040–max
Sulfur	0.030–max
Chromium	17.00–19.00
Nickel	12.00–14.00
Molybdenum	2.00– 3.00
Copper	0.50–max

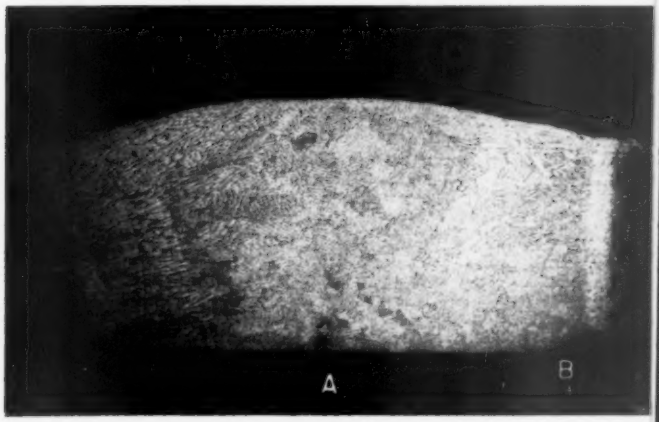

Fig. 3 Argon-backed weld—PWA-673

Test plates were welded under identical conditions with argon and nitrogen being alternated as the backing gases. All materials were from identical heats. Various thicknesses were used. The nitrogen contents of all materials and the deposited weld metal was determined. Tests were also evaluated by X-ray examination, tensile specimens, and face and root bends. Photomicrographs were made for visual examination. The martensitic stainless steel was tested in the as-welded, stress-relieved and heat-treated conditions. All test plates were in the annealed state prior to welding. All weldments were made by the inert-gas-shielded process

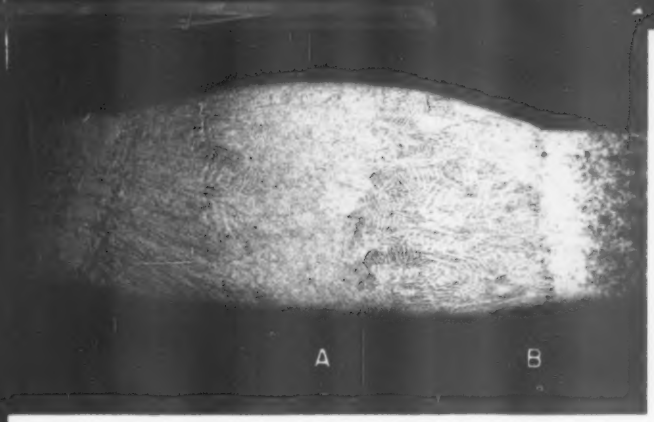

Fig. 4 Nitrogen-backed weld—PWA-673

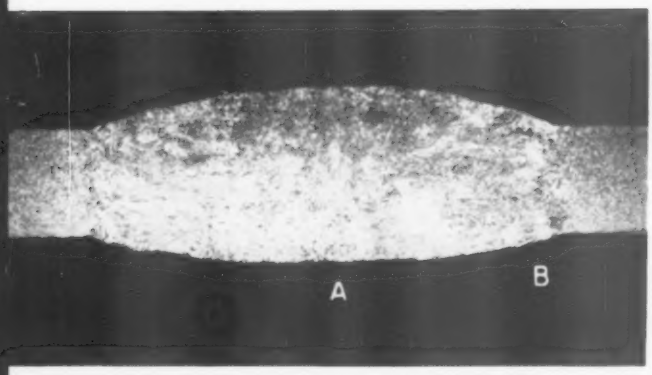

Fig. 5 Argon-backed weld—AMS-5504

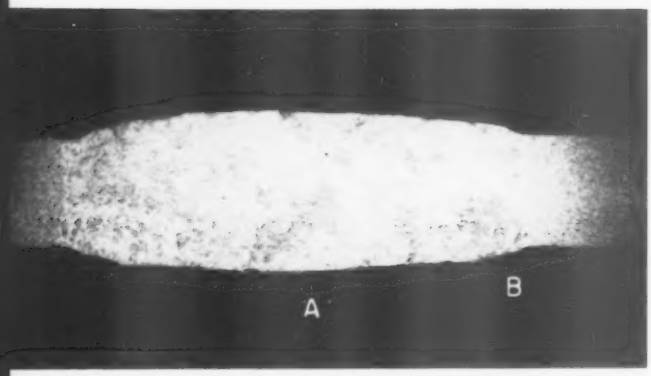

Fig. 6 Nitrogen-backed weld—AMS-5504

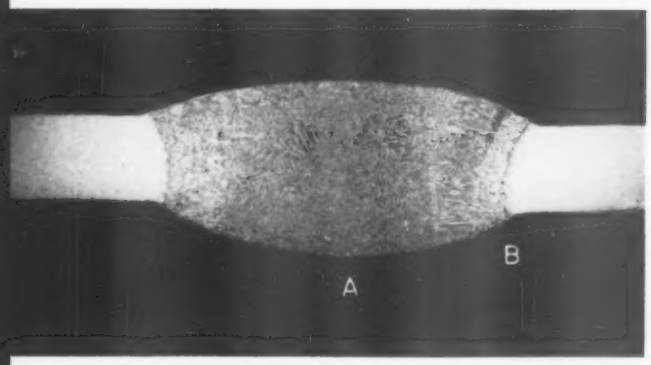

Fig. 7 Argon-backed weld—AMS-5524

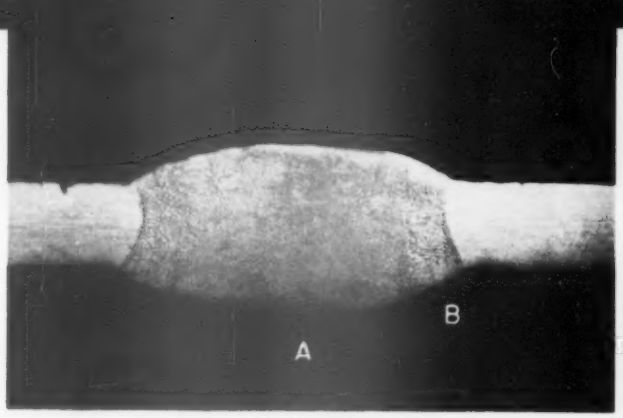

Fig. 8 Nitrogen-backed weld—AMS-5524

Results

PWA-673 Material

Nitrogen content of base metal	0.035%
Nitrogen content of filler wire	0.065%
Nitrogen content of weld—argon backed	0.046%
Nitrogen content of weld—nitrogen backed	0.047%

Tensile tests, face and root bends, X-ray examination, and photomicrographs of the nitrogen-backed weld were equal to the argon-backed welds. Figures 3 and 4 show a macrograph cross section.

410 Material—as-welded

Nitrogen content of base metal	0.040%
Nitrogen content of filler wire	0.051%
Nitrogen content of weld—argon backed	0.045%
Nitrogen content of weld—nitrogen backed	0.051%

Tensile tests, X-ray examination and photomicrographs of the nitrogen-backed weld were equal to the argon-backed welds. Macros at × 10 magnification are shown in Figs. 5 and 6.

410 Material—as-welded and stress-relieved

Nitrogen content of base metal	0.040%
Nitrogen content of filler wire	0.051%
Nitrogen content of weld—argon backed	0.041%
Nitrogen content of weld—nitrogen backed	0.044%

Tensile tests, face and root bends, X-ray examination, and photomicrographs of the nitrogen-backed welds were equal to the argon-backed welds.

316 Material

Nitrogen content of base metal	0.045%
Nitrogen content of filler wire	0.042%
Nitrogen content of weld—argon backed	0.058%
Nitrogen content of weld—nitrogen backed	0.074%

Tensile test, face and root bends, X-ray examination, and photomicrographs of the nitrogen-backed welds were equal to the argon-backed welds. Figures 7 and 8 show a visual comparison.

The loss of delta ferrite in the alloys tested means a loss of ductility; and an excess of nitrogen will kill the delta ferrite. However, 0.0125% of nitrogen will go into solid solution for each 1% of chromium contained in the alloy. Thus an alloy containing 18% chromium would have a tolerance for approximately 0.225% of nitrogen.

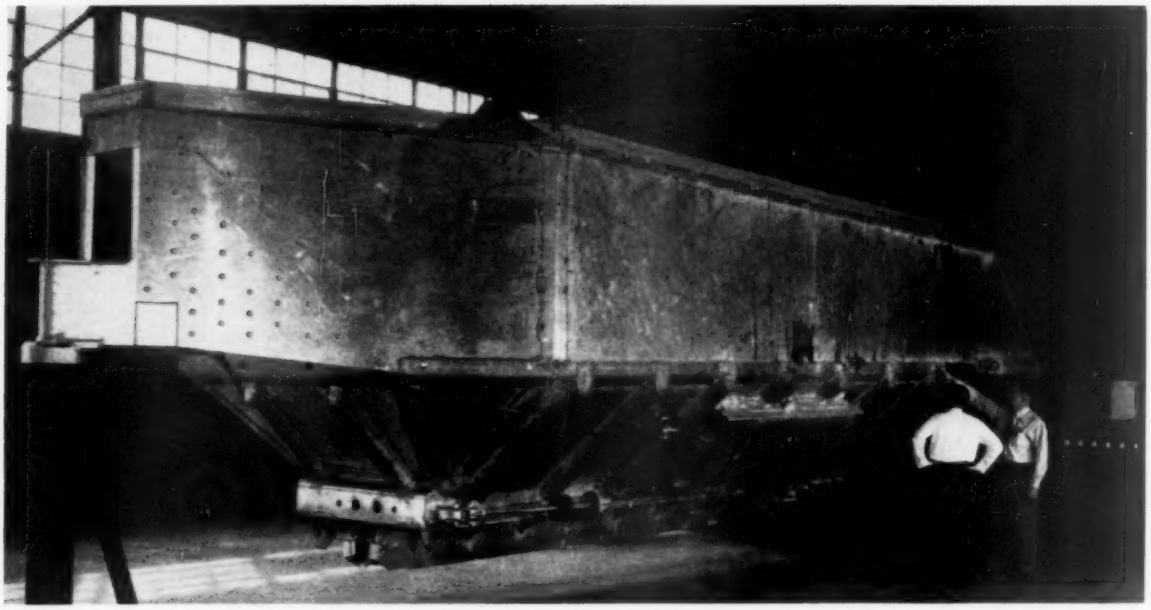

Fig. 1 Made with gas-shielded tungsten-arc cutting and gas-shielded metal-arc welding, this 11 3/4 ton trailer is ready for delivery to Aluminum Company of America. Coal will be emptied through the drop-bottom doors

THE BIRTH OF GOLIATHS

Huge coal trucks will haul 60 tons a trip

BY CHARLES MITCHELL AND H. R. MILLER

Six 60-ton capacity trailers—believed to be the largest aluminum coal trucks ever built—were fabricated with gas-shielded tungsten-arc cutting and gas-shielded metal-arc welding at General American Transportation Corp., East Chicago, Ind.

Coal hauled in the mammoth trucks will be used to generate electricity for the new aluminum reduction plant of Aluminum Company of America, near Evansville, Ind.

The 23,500-lb trailers weigh about 10 tons less than a steel trailer of the same size—a weight savings of almost 50% that increases pay-load capacity while lowering operating costs. In addition, the aluminum trailers resist corrosion far better than steel, resulting in longer life and reduced maintenance costs.

Each trailer consists of ten major subassemblies. Except for minor part preparation with a mechanical cutting method, the aluminum "goliaths" were fabricated almost completely with the gas-shielded welding and cutting team. Many of the parts were prepared by gas-shielded tungsten-arc cutting and all the parts were joined by gas-shielded metal-arc welding.

Parts were made from type 5456 aluminum plate and extruded shapes which varied from 3/8- to 5/8-in. thick. Clean, smooth cuts—some as long as 27 ft—were made at speeds of 250 ipm with a tungsten-arc cutting torch mounted on a portable carriage.

All welds, mainly 3/8-in. thick fillets, were made with portable gas-shielded metal-arc welding machines and protected from contamination by 99.995% pure argon. As shown in Figs. 1 through 5, the gas-shielded metal-arc welding machines were easily transported through the GAT plant to weld the various crossbeams, drop-bottom doors, side sections and other subassemblies. About 200 lb of type 5356 filler wire, 3/32 in. diam, were consumed per trailer.

Each completed trailer has a 37-ft length, 11-ft inside width, 9-ft inside height, and a capacity of 70 cu yd. These giant trucks perform a giant job, hauling thousands of tons of coal a day from a strip mine.

Charles Mitchell is Manager, Plant No. 3, General American Transportation Corp., East Chicago, Ind., and **H. R. Miller** is a welding sales engineer, Linde Co., Chicago, Ill.

Fig. 2 Trailer parts are cut to size: a tungsten-arc cutting torch, mounted on a portable carriage, accurately slices $^{3}/_{8}$-in. thick aluminum plate at a speed of 250 ipm

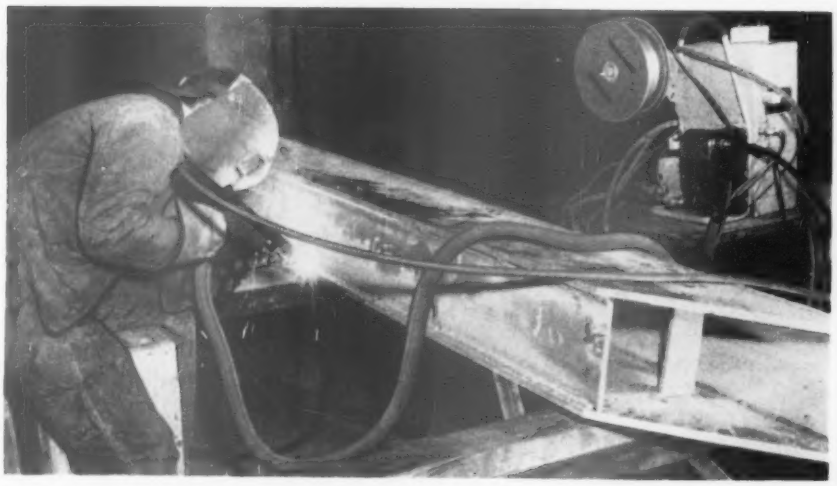

Fig. 3 Using a portable gas-shielded metal-arc welding machine and type 5356 aluminum wire, a GAT operator joins $^{1}/_{2}$-in. thick aluminum plates in fabricating a trailer's lower rear crossbeam

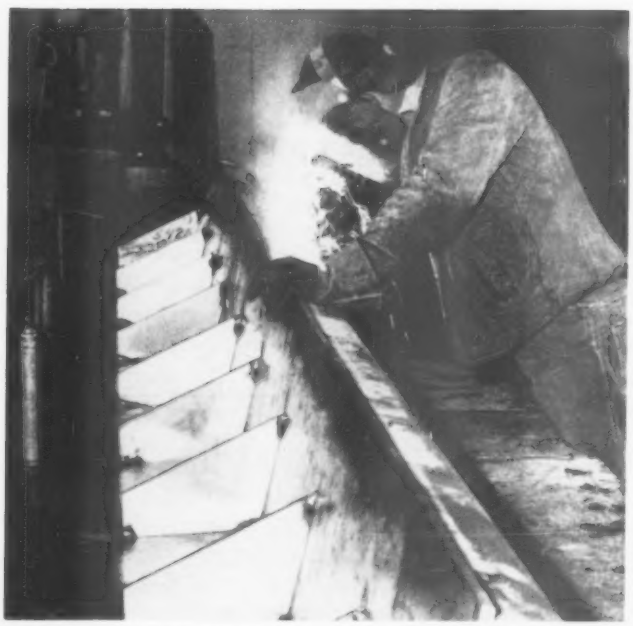

Fig. 4 A 22-ft long section of a drop-bottom door is gas-shielded metal-arc welded with $^{3}/_{32}$-in. diam aluminum wire. The air-operated doors will be used to empty the huge load of 60 tons of coal

Fig. 5 With 99.995% pure argon gas shielding the weld zone, a GAT operator welds a side-section subassembly

WELDED SLICK RAIL FOR DRY-CLEANING PLANT

Fig. 1 "J" hooks are welded into position to provide a continuous slick rail for a dry-cleaning plant

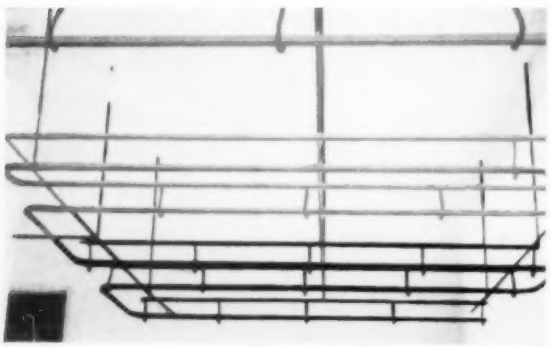

Fig. 2 Partially painted section of slick rail shows how neatly it blends into the background

For a long time, dry cleaners everywhere have looked for a low-cost slick rail for their plants. It enables them to slide clothes from one machine to the other. And it keeps a constant flow of clothes moving between cleaning operations, instead of an intermittent supply transported in carts. It also makes final assembly of clothes by order easier.

The main drawback to installing slick rail, according to dry cleaners, has been the cost of material and the time taken to install it. However, the method developed by Webb's Machine Repair Service in Peoria, Ill., overcomes that objection. Their technique saves time, money and effort. What's more, the owner gets the benefit of a custom job designed to go exactly where it will do him the most good.

Webb's steps to install a slick rail are relatively simple. Most cleaners know exactly how they want their plant laid out, and the best way to lay out the slick rail route is by chalking it on the floor. Next, 3-in. long, $^3/_8$-lag bolts are welded to one end of 4-ft lengths of $^3/_8$-in. pipe. One-quarter inch holes are drilled into the ceiling joists at 4-ft intervals. The lag bolts are then screwed into the ceiling joists. The hanging lengths of pipe are marked 6 ft, 6 in. from the floor, and cut with a pipe cutter. Lengths of $^1/_2$-in. pipe are welded to the bottom of the legs. Next, $^3/_8$-in. lengths of pipe are welded at 90 deg to the $^1/_2$-in. pipe directly underneath each leg. J hooks are welded every 2 ft on the $^3/_8$-in. pipe (Fig. 1). (The J hooks are made from $^3/_8$-in. bar stock, rolled in a jig and cut to 8 in. long.) Finally, the slick rail is welded to the curved tip of the J hook. A completed installation is shown in Fig. 2.

The rail is $^1/_4$ in. x $1^1/_4$ in. x 16 ft. It is easily bent to the desired contour by hand.

A typical installation at one dry-cleaning plant took seven hours. Each four feet of rail was tested with 800 lb of weight after it was in place. Fabricator's cost breakdown showed a savings to the cleaner of $150.00 over quotations for other methods of installation.

Based on a story by Hobart Brothers Co., Troy, Ohio.

January 15, 1959 Is Deadline for 1959 National Fall Meeting Abstracts

Papers dealing with latest developments in (1) welding as applied to automotive manufacturing operations, (2) resistance welding, (3) fabrication of "honeycomb" structures, (4) fabrication and maintenance of equipment used for radioactive applications, (5) pressure vessels and storage tanks, (6) equipment and pipe lines used in petroleum industry, (7) machinery design and fabrication, (8) structures, (9) automation as applied to resistance welding, inert-gas-shielded arc welding, and other welding processes, (10) sur-

Fig. 1 View of electrode holder after machining but before welding

Fig. 2 Weld pad on left has been peened; the one at right has not

Fig. 3 Welded pad is shown at top; bottom pad is ready for welding. Brick work is part of heating furnace

Maintenance on electric furnaces is made less expensive as

GAS-SHIELDED METAL-ARC WELDING AIDS RESURFACING OF COPPER ELECTRODE HOLDERS

An efficient and economical maintenance job on copper electrode holders has been accomplished at a large Eastern steel company by means of the gas-shielded metal-arc welding process. These copper holders are used to grip huge electrodes which induce heat in an electric furnace used to melt and refine many grades of iron and steel.

After prolonged service, inner surfaces of the holders become arced and worn and pads must be built up again to receive the electrodes properly. Rebuilding by metal-arc welding restores effective mechanical gripping and the completed buildup assures efficient conductivity of current to the electrode.

To rebuild the holders a gas-shielded metal-arc welding gun, operating at 425 amp with a mixture of 30 cfh argon and 10 cfh helium, was used. Two layers of copper filler metal were deposited on each surface with a total of five hours arc time per pad. Wire feed speed ranged between 275 ipm on the first pass to 340 ipm on the finish pass.

Prior to welding, the castings were carefully prepared in order to guarantee a quality repair job. The arced areas were chipped or machined to expose clean metal (Fig. 1). With the chipping completed, the entire area to be welded was thoroughly peened to close any porosity in the casting and insure good fusion to the base material on the first pass. Depending on the quality of the casting, intermittent peening was required as the first layer progressed (Fig. 2).

A brick enclosure, built around the holder, was preheated to 800° F. Enough of the brickwork was removed to allow welding to proceed when the casting temperature had dropped to 600° F (Fig. 3). The deep holes were filled first. When the surface was level, two or three layers of weld metal normally were required to restore the original contour of the electrode-holder pad.

Based on a story by the Air Reduction Sales Co., New York, N. Y.

facing, (11) maintenance, (12) welding of castings and composite structures, (13) welding of dissimilar alloys or alloy systems, (14) welding of aluminum, magnesium, zirconium, titanium, Inconel and like metals, (15) brazing, (16) soft soldering, (17) welding of plastics, and (18) practical applications or "how-to-do" topics. However, any papers dealing with the educational and informative categories of welding production, engineering, research and metallurgy, are welcomed as long as the subject falls within the field of our SOCIETY's activities.

To assure consideration for the 1959 National Fall Meeting Program abstracts must reach AWS not later than Jan. 15, 1959. Application forms, if needed, may be obtained by writing to National Secretary, AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

ALUMINUM SPIRAL RIBS APPLIED BY CONTINUOUS ULTRASONIC WELDING

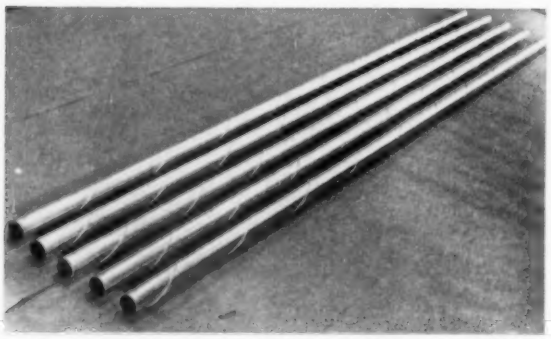

Fig. 1 Thin wall aluminum tube over 15 ft long to which spiral aluminum ribs were seam welded by overlapping ultrasonic spot-type welds

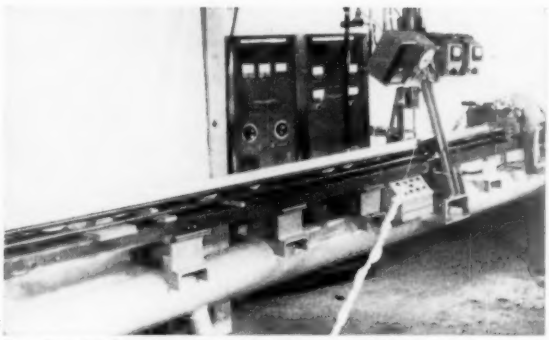

Fig. 2 35 foot long ultrasonic seam welder used to attach spiral aluminum ribs to aluminum tubes

A typical application of ultrasonic continuous welding is the joining of aluminum ribs to aluminum tubes.

Figure 1 shows tubes over 15 ft long to which aluminum spiral ribs were continuously welded by a series of overlapping ultrasonic spot-type welds. These assemblies were fabricated in a machine over 35 ft long which was completely automated including indexing of the tube, locating the rib, spacing of the spot welds and complete cycling of the welding operation. Once the operator started the machine, the 15-ft rib-tube assembly was completely welded without further effort by the operator.

Figure 2 is a picture of the automatic ultrasonic seam welder showing its instrumentation and automatic controls.

Based on a story by Aeroprojects Inc., West Chester, Pa.

BALANCING THE UNBALANCED

An unusual job plus ingenuity added up to this special arc-welding setup at Baker Perkins Inc., Saginaw, Mich. The job was welding low-carbon-steel axles to a 650-lb, S-shaped, cast stainless-steel mixer blade—this one for mixing solid-liquid rocket and missile fuels (Fig. 1).

The ingenuity came in designing a positioner utilizing an old lathe chuck and a variable-speed drive to both hold and rotate the work—thereby enabling the operator to make deep penetrating welds around the circumference of the 4-in. diam axles. The axles are shrunk fitted to the blade body prior to welding.

Foot-pedal arrangement enables operator to control the powered positioner as he applies the stainless-steel welding electrode. About 4 hr are required to complete the work.

Fig. 1 Welding low-carbon-steel axle to cast stainless-steel mixer blade

Based on a story by Baker Perkins Inc., Saginaw, Mich.

Society News

Technical Papers Selected for AWS 40th Annual Meeting in Chicago

Record-shattering number of applications received by Technical Papers Committee. Three sessions to be sponsored by AIEE and two by SSC

A program which promises the presentation of the highest quality papers ever given at a national meeting of the AMERICAN WELDING SOCIETY has been formulated for the 40th Annual meeting in Chicago, April 6–10. Abstracts of papers submitted to the SOCIETY'S Technical Papers Committee far exceeded the acceptable number of 48. In addition, the American Institute of Electrical Engineers has selected 9 papers and another 6 have been chosen by the Ship Structure Committee, making a grand total of 63 papers within the 21 scheduled sessions.

The quality of the Chicago program is reflected in the balance of the papers selected for presentation, ranging from practical applications through research. Two sessions each will be held on nuclear-power equipment and welded structures. Other sessions will feature processes and procedures, cutting, pipe lines, design considerations, gas-shielded welding, brazing, stainless steel, titanium and zirconium, aluminum alloys, resistance welding, ultrasonic welding, heat effects on steel weldments, and weldability of steel and cast iron.

The three AIEE-sponsored sessions will cover arc-welding power supplies, welding-arc fundamentals and resistance welding. The subjects of the Ship Structure Committee's two sessions will deal with brittle fracture and welding in ship structures.

All sessions will be held at Chicago's Hotel Sherman from April 6th through 10th. Morning and afternoon sessions will be featured on Tuesday and Wednesday, with afternoon sessions on Monday and morning sessions only on Thursday and Friday. Special lectures will include the traditional Adams Lecture on Monday morning and the Educational Lecture Series on Monday and Tuesday afternoons.

This 40th Annual Meeting will present many practical application papers. Most of these emanate from fabricators throughout the country. Other papers come from university research staffs, government groups and research organizations. An innovation at this meeting will be the presentation of a Japanese paper in the session dealing with heat effects on steel weldments.

The three-day Welding Show, featuring exhibits and demonstrations of the latest equipment, filler metals and supplies used in the welding industry, will be staged in Donovan Hall.

The tentative technical-papers program will be published in the January 1959 issue of THE WELDING JOURNAL.

AWS DIRECTORS-AT-LARGE

Term Expires: 1959	1960	1961
J. H. Blankenbuehler	J. F. Deffenbaugh	A. A. Holzbaur
G. E. Linnert	A. E. Pearson	D. B. Howard
P. G. Parks	C. M. Styer	C. E. Jackson
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District No. 1•New England Sidney Low

District No. 2•Middle Eastern E. E. Goehringer

District No. 3•North Central H. E. Miller

District No. 4•Southeast E. C. Miller

District No. 5•East Central H. E. Schultz

District No. 6•Central J. N. Alcock

District No. 7•West Central A. F. Chouinard

District No. 8•Midwest F. G. Singleton

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Junior Past-President J. J. Chyle

Junior Past-President C. P. Sander

Charles I. MacGuffie

NATIONAL OFFICERS FOR 1959–60 NOMINATED BY AWS

The National Nominating Committee of the AMERICAN WELDING SOCIETY has submitted a list of seven nominees for approval by the entire membership. Ballots will be mailed on or before Dec. 26, 1958, and, according to the National Bylaws, must be returned to national headquarters by Jan. 26, 1959, in order to receive recognition.

This carefully selected committee, composed of a chairman, three members-at-large and eleven district representatives, has nominated an imposing slate of members to serve the 12,000-member group during the 1959–60 fiscal year.

Heading the list of nominees is Charles I. MacGuffie of Air Reduction Sales Co. as President. R. D. Thomas, Jr. of Arcos Corp. and A. F. Chouinard of National Cylinder Gas have been named First and Second Vice-Presidents, respectively. Jay Bland, Frank Singleton, Charles B. Smith and J. R. Stitt have been nominated Directors-at-Large.

The District Nominating Committees, composed of representatives from each of the SOCIETY's eleven districts, have selected six men to serve as District Directors for the 1959–61 term. They are: George W. Kirkley, District #1; Joseph W. Kehoe, District #3; Harold E. Schultz, District #5; Lester L. Baugh, District #7; Clifford L. Moss III, District #9; and C. B. Robinson, District #11.

Nominated for President

Charles I. MacGuffie

Mr. MacGuffie brings with him a wealth of nearly 35 years' experience in the welding industry. He obtained a B. S. degree in electrical engineering in 1925 from Pennsylvania State University and joined General Electric Co. immediately upon graduation, completing a test course at the outset of his G.E. career. In 1928 he was appointed a welding specialist in the Atlanta District, operating out of Philadelphia. Mr. MacGuffie was recalled to the home office in 1939 where he was named Assistant Manager of Sales, Welding Divisions. Appointed Manager of Marketing, Welding Department, in 1951, he served in this capacity until November 1st of this year, at which time he joined Air Reduction Sales Co. In his new position as Manager of Airco's newly formed Special Products Department, Mr. MacGuffie will supervise the design of complete welding systems. The nucleus of this new group is comprised of personnel from the former Machine Welding Department.

Listed among his previous SOCIETY activities are Chairman of the Philadelphia Section; Member-at-Large, Board of Directors; Chairman of the Manufacturers, Public Relations and Exposition Committees; and a member of THE WELDING JOURNAL, Reserve Funds and Technical Papers Committees.

A Past Chairman of the Welding Section of NEMA, Mr. MacGuffie also holds memberships in the AIEE and the American Ordnance Assn.

Nominated for First Vice-President

R. D. Thomas, Jr.

Born in Oakmont, Allegheny County, Pa., Mr. Thomas received his B.S. degree in Chemistry in 1937 from Cornell University. His master's degree, also from Cornell, was conferred shortly thereafter, largely on the basis of his thesis, "Reactions in Electric Arc Welding."

In 1937 Mr. Thomas was appointed Director of Research and Engineering

at the Arcos Corp. in Philadelphia. A Vice-President in 1945, an Executive Vice-President in 1955, he was named President of Arcos in 1956.

A Past Chairman of the Philadelphia Section, Mr. Thomas has been especially active on technical committees. He is chairman of the High Alloys Filler Metal Subcommittee, a member of the Subcommittees for Low Alloy Electrodes and Nickel Alloy Electrodes, and a former member of the Subcommittee for Copper Alloy Electrodes. He was Secretary (1946–50) of the Joint Navy-NEMA Committee charged with the development of low hydrogen-ferritic electrodes. With the Welding Research Council Mr. Thomas was Secretary (1948–51) of the High Alloys Committee. Also, he was a member of Subcommittee on Corrosion and on Welding of Stainless Steels. He is a member of the AEC Advisory Committee for project on welding Type 347 steels. He was an advisor to the National Research Council Committee on Welding during World War II, and, in 1952, served as a member of an informal committee formed by National Academy of Sciences to report on opportunities of nickel conservation in alloy-welding applications. Industry Coordinator, Electrode Group for the Ordinance Advisory Committee for the Welding of Armor, he also holds membership in two specification and research groups.

Mr. Thomas has taught various courses at Temple University and Drexel Institute of Technology. He was instrumental in establishing courses in welding at Drexel in 1952.

A recipient of the 1958 Miller Medal, he has delivered papers at local and national AWS meetings, as well as in Switzerland and Belgium.

Nominated for Second Vice-President

A. F. Chouinard

Graduated from Purdue University in 1931 with a B.S. degree in Electrical Engineering, Mr. Chouinard has spent all of his professional life in the engineering field.

He has worked in an engineering capacity for the Chicago Surface Lines, the Champion Chemical Co. and Stewart-Warner Corp.

Since 1939 he has been employed by National Cylinder Gas Co. During this time, Mr. Chouinard has designed many types of welding and cutting equipment and machines, and has some 20 patents issued in his name. For the past 14 years he has been Manager of the Research and Development Department of NCG. He has just recently been appointed Director of Research and Development for the NCG Division, and his department is now responsible for the development and application of all of the company's products and processes.

Mr. Chouinard has been active in the AWS in both local and national activities. He is a past chairman of the Chicago Section and is currently director of District #7.

In 1957, Mr. Chouinard was appointed chairman of the Section Advisory Committee. Aside from his AWS post as Director of District 7, he is Chairman of the Voting Committee of the Organization Structure Committee and is a member of the Executive, Finance, Membership Committees and the Technical Council.

He has presented many technical talks to AWS Sections throughout the country. These talks include discussions on oxygen cutting, metallurgical aspects of flame hardening, specialized cutting applications, foundry applications of many oxyacetylene processes, etc. Mr. Chouinard has also written several technical articles which have appeared in different trade journals.

He was Chairman of the Committee that prepared Chapter 4 (Gas Welding Equipment and Materials), for the Third Edition of the WELDING HANDBOOK, published in 1948, and also was a member of committees preparing other chapters for this edition. Mr. Chouinard is presently chairman of the committee that is preparing Chapter 23 (Gas Welding Equipment and Materials) for the Fourth Edition of the WELDING HANDBOOK.

In addition to the AWS, Mr. Chouinard is a member of the IAA, the AISE, ASM and is a registered professional engineer in the state of Illinois. He is also a member of the Chicago Engineers Club.

Nominated for Director-at-Large 1959–62

Jay Bland

Mr. Bland's educational background includes a B.S. degree in 1933 from the University of Rochester and an M.S. in Metallurgy the following year from Columbia University. In 1934 he was appointed Metallurgist for Sun Oil Co.'s installation at Marcus Hook, Pa. Moving to New York in 1939, Mr. Bland became Metallurgist and Senior Welding Engineer at the New York Naval Shipyard in Brooklyn. He was Welding Engineer from 1951 through October of this year for Standard Oil Co. in Whiting, Ind. It was within this organization that he headed the firm's Metals and Welding Section of the Engineering Research Dept. Mr. Bland became affiliated with the Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y., on October 16th. His new title is that of Consulting Engineer, Welding Metallurgy and Development.

Recipient of the 1956 Lincoln Gold Medal, Mr. Bland has authored many technical papers covering welding and inspection, and has addressed many AWS sections on these subjects. He is also a Past Chairman of the Chicago Section and has been a member of 1957–58 National Nominating Committee and the Committee on Awards. Mr. Bland also served on the committee responsible for the preparation of the section on inspection of the WELDING HANDBOOK.

He is also a member of ASM, SNT, ϕBK, ΣX and several committees of the Welding Research Council.

Nominated for Director-at-Large 1959–62

Frank Singleton

Mr. Singleton was educated in the school system of Kansas City, Mo., his birthplace, and graduated from the University of Kansas City. His background includes employment in the Welding Division of the Fisher Body plant in Kansas City; squadron commander in the Air Force during World War II; a pilot for TWA; and seven years as a salesman for a welding distributor. At present, Mr. Singleton owns and operates Singleton Welding Supply in Kansas City.

A Past Chairman of the Kansas City Section, he was Chairman of the Arrangements Committee for the 1955 AWS Annual Meeting. Presently in his second term as Director of District #8, Mr. Singleton has served on the national Finance, Section Advisory and Membership Committees.

Mr. Singleton is married and the father of six children.

Nominated for Director-at-Large 1959–62

Charles B. Smith

Born in Brawley, Calif., Mr. Smith received his degree in Mathematics with minors in Chemistry and Physics in 1937 from UCLA. He also spent several years of graduate work in Math and Physics.

After joining the Santa Monica Division of Douglas Aircraft Co., Inc. in 1939, Mr. Smith was transferred to the company's Long Beach Division two years later and was appointed Resistance Welding Engineer. In 1945 he was named Chief Welding Engineer and was promoted to his present position of Assistant Chief Materials and Processes Engineer in 1955.

Within the SOCIETY, Mr. Smith has been Chairman of the Los Angeles

Section and 1957–58 National Membership Chairman. He was also chairman of the committee which prepared the section on aircraft welding of the Third Edition of the WELDING HANDBOOK.

Mr. Smith has served on various "expert" panels in technical meetings throughout the state of California, including the Western Metals Congress. He has also contributed to the literature of many technical magazines as an authority on his specialty of aircraft welding.

A registered mechanical engineer in the state of California, Mr. Smith holds membership in ΦΔΚ.

Nominated for Director-at-Large 1959–62

J. R. Stitt

From his birthplace in Youngstown, Ohio, Mr. Stitt attended Pennsylvania State University where he received a B.S. degree in Civil Engineering in 1930. After graduation, he was appointed Field Engineer for the Austin Co. and in subsequent years represented several manufacturers of welding equipment and electrodes. Mr. Stitt rejoined the Austin Co. in 1937 as Field Engineer and Inspector. In 1938 he joined the faculty of Ohio State University where he organized and taught the first complete curriculum in Welding Engineering. During his tenure as Assistant and Associate Professor at Ohio State, 26 students were graduated with degrees in Bachelor of Industrial Engineering (Welding Engineering).

Mr. Stitt has been in his present position, that of Research and Welding Engineer at The R. C. Mahon Co. in Detroit, since 1945. His company fabricates and erects structural steel in various forms as well as a great variety of weldments.

Mr. Stitt has served AWS as Director-at-Large and Director of the original District #4. In addition to his membership on various national committees, he is a Past Chairman of the Detroit Section and a 1956 recipient of the Meritorious Certificate Award.

A registered professional engineer, Mr. Stitt was the first engineer in Ohio registered in welding. He is a member of ASM, SNT, ASTM, ΧΣ, TBII, The Engineering Society of Detroit, Corrosion Engineering Society and Society for Experimental Stress Analysis.

Nominated for District Director 1959–61

George W. Kirkley

District 1, New England

A graduate of Virginia Polytechnic Institute, Mr. Kirkley was employed by M. W. Kellogg Co. as a welding specialist. One of his assignments, in 1952, had been the introduction of industrial radiography to the country of Israel. Mr. Kirkley had used isotopes from the British Atomic Energy installation in Harwell, England, for this purpose. In this same capacity he conducted courses for Israeli engineers and technicians in the welding and nondestructive inspection of high-pressure high-temperature piping systems. Mr. Kirkley joined his present employer, the Electric Boat Division of the General Dynamics Corp., at Groton, Conn., in 1953. At that time he developed the procedures for the welding of the reactor piping for the *Nautilus*, the first nuclear-powered submarine. At present he is both Welding Consultant to Electric Boat's Design Department and Nuclear Projects and Welding Engineer for Electric Boat's Research and Development Department.

A member of the Atomic Energy Commission's Welding Committee, Mr. Kirkley is also a member of the AWS Subcommittee on Nuclear Power Piping. In addition to being a lecturer of the Atomic Institute, Mr. Kirkley has spoken to various AWS sectional audiences. He is currently Chairman of the Hartford Section and served as the Technical Chairman for the recent New England Regional Welding Conference.

Joseph W. Kehoe

District 3, North Central

Born in Conshohocken, Pa., Mr. Kehoe graduated from Villanova University in 1934 with a Bachelor of Science degree in Electrical Engineering. He joined Westinghouse in 1936, spending three years on the Motor Division Test Floor. Later he became associated with metals joining process development work in the newly formed Headquarters Manufacturing Engineering Department. In 1950 Mr. Kehoe was appointed to his present position, that of Manager of the Headquarters Manufacturing Metals Joining Section. This particular laboratory is a corporation-wide function of Westinghouse, responsible for the development and improvement of manufacturing techniques involving welding processes throughout the entire Westinghouse setup. Mr. Kehoe chairmanned the firm's Metals Joining Committee from 1950 to 1956.

In 1950 he was awarded the RWMA Industrial Award for his paper, "A Practical Method for Obtaining Consistent Resistance Welds," adjudged best in the contest. A member of the 1957 ASTE Handbook Review Committee of the chapter dealing with hot joining of metals, he is also co-author of the text entitled, "Flash Welding, Upset-Butt Welding and Other Processes and Equipment," now being used in the I.C.S. revised course on resistance welding.

Mr. Kehoe is chairman of the AWS Resistance Welding Subcommittee I—Resistance Welding of Mild Steel, and is also a member of Subcommittees III and V on Aluminum and Stainless Steel, respectively.

He is a registered professional engineer in the state of Pennsylvania.

Harold E. Schultz

District 5, East Central

Manager of Applications and Processes Engineering at General Electric, Evendale, Ohio, Mr. Schultz is a graduate of Oklahoma A & M. He joined General Electric in 1942, serving first in the Engineering Test Program. From 1943 to 1951 he was a Welding Engineer at the Thompson Laboratory, General Electric River Works, Lynn, Mass., and in the spring of 1951 received the assignment of organizing and heading up the Welding Unit of the Aircraft Gas Turbine Plant Laboratory in Evendale, Ohio. This led, in 1953, to the position of Manager of Welding and Heat Treatment in the Materials Laboratory of the AGT Development Department. His present duties include the application of new developments in the field of processes and materials to advanced jet engine design and manufacture.

Mr. Schultz filled the vacancy created by the death of Lew Gilbert as Director of District 5. A Past Chairman of the Cincinnati Section, he is a member of the Aircraft Advisory and Resistance Welding Committees of the Welding Research Council. In 1957 Mr. Schultz served as General Chairman of the Central States Welding Conference in Cincinnati.

Lester L. Baugh

District 7, West Central

Mr. Baugh became associated with Allis Chalmers Manufacturing Co., Springfield Works, in 1936 as a welder. The next year, 1937, he was promoted to welding foreman and held this position until 1944 at which time he became general foreman in charge of the welding processes at the Springfield Plant. In 1948, after four years as general foreman, he became the Welding Process Engineer and is presently serving in this capacity.

He graduated from the Lincoln Electric School in Welding, and attended the John Huntington University. He has completed an extension course from the University of Illinois in Welding Engineering.

Mr. Baugh is a member of the Sangamon Valley Section which he helped promote and organize in 1952, and served as this section's first secretary. He is now a past chairman of this section, and is presently serving his fourth term as the section's secretary.

Mr. Baugh was instrumental in promoting and planning the first Welding Show to be held in this section. This Welding Show is now in its sixth year of operation.

In 1957, Mr. Baugh was elected representative from District Number 7 to the National Nominating Committee, and attended the meeting in Philadelphia. He was elected again to the same office in 1958, and has attended and participated in all of the meetings of this committee.

Clifford L. Moss III

District 9, Southwest

A native of Dallas, Tex., Mr. Moss obtained a Bachelor of Science degree in Industrial Engineering from MIT in 1948. During World War II he was a bombadier in the 8th Air Force.

Mr. Moss joined the Estimating Department of Wyatt Metal and Boiler Works in March 1948 and was promoted to Chief Estimator in 1950. He was named Production Manager of the same Dallas firm in April 1957.

Active in the former Dallas Section (now the North Texas Section), Mr. Moss has served as its chairman and program chairman. He was also the Section's delegate to the AWS 1958 National Spring Meeting in St. Louis.

A member of ASME and AIIE, Mr. Moss is a Texas Registered Professional Engineer. He is married and has one daughter.

C. B. Robinson

District 11, Northwest

Mr. Robinson was born in Philadelphia, Pa., in 1906. He is a graduate of the University of California. From 1939 to 1944 he was employed by the Mare Island Shipyard in the capacity of welding engineer. He became associated with Air Reduction Pacific Co. as welding service engineer in 1944 and in 1950 became supervising welding engineer in charge of process engineering.

Mr. Robinson has been a member of the AMERICAN WELDING SOCIETY for 29 years, having joined in 1929. During these years he has served the SOCIETY as Section technical chairman of the AWS San Francisco Section, in 1955.

As current Director of District 11, Mr. Robinson is a member of the Membership and Section Advisory Committees. He is also the author of various articles on welding processes and electrodes.

Mr. Robinson is a member of the ASM, ASNE, Navy League of the United States and American Ordnance Assn.

District Representatives Selected for the National Nominating Committee

Eleven nominees to serve the 1959–60 term as District Representatives on the National Nominating Committee have been selected. Their names and addresses are listed as follows:

District No.	*Nominee*
1	F. H. Domina, General Electric Co., M & P Lab., Bldg. 7, Schenectady, N. Y.
2	A. Clemens, Jr., Arcrods Corp., P. O. Box 6686, Sparrows Point 19, Md.
3	M. H. Robinson, Dresser Mfg. Div., Dresser Industries, Inc., Bradford, Pa.
4	Ed A. Holder, Ingalls Shipbuilding Corp., Pascagoula, Miss.
5	P. J. Rieppel, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio
6	Kieth Sheren, Taylor-Thompson Machinery Co., (Res.) 6650 Hartwell, Dearborn, Mich.
7	Leslie S. McPhee, Whiting Corp., 15700 Lathrop Ave., Harvey, Ill.
8	A. G. Hedstrom, Kansas City Structural Steel, 21st & Metropolitan, Kansas City, Kans.
9	Hubert F. Crick, Mosher Steel Co., Houston, Tex.
10	David P. O'Connor, Dept. of Water and Power, City of Los Angeles, (Res.) 3222 Sheffield Ave., Los Angeles 32, Calif.
11	M. M. Griffith, Food Machinery & Chemical Corp., (Res.) 10223 Doncaster Way, San Jose 27, Calif.

Final election results will be published in the May 1959 issue of THE WELDING JOURNAL. Elected nominees will officially assume office on June 1, 1959.

PVRC Holds Annual Meeting

The annual meeting of the Pressure Vessel Research Committee (PVRC) of the Welding Research Council was held on Friday, September 26th, at the Engineers' Club, New York, to review the progress and accomplishments of the committee since its formation in 1945.

The PVRC collects and correlates existing information, develops new data and acts as a research and development agency for the principal code-making bodies. The committee also acts for many power, petroleum and chemical industries, for government agencies such as the Bureau of Ships of the Navy and the Atomic Energy Commission. Consisting of three divisions—Materials, Design and Fabrication—the PVRC has approximately 200 scientists and engineers serving on its committees.

The meeting was opened by Fred L. Plummer, Chairman of PVRC and the National Secretary of the AMERICAN WELDING SOCIETY.

Mr. Plummer cited various examples where PVRC research findings had influenced the acceptance of standards; created a more complete understanding of material, design and fabrication problems; and had determined methods of resolving these problems in the most economical manner. The savings made possible by the revision of codes alone had been many times greater than the total contributions to the program. The Navy's tentative design basis for atomic-reactor pressure vessels was another example incorporating the results of PVRC research.

• WATCH
• WELDING
• JOURNAL
• JANUARY

THINGS YOU SHOULD KNOW

(That happened in September and October)

● President Hoglund joined members of the Niagara Frontier Section on September 25th to honor "Is" Morrison and presented to him a District Meritorious Award in recognition of the many fine contributions he has made in local and national activities of the SOCIETY.

● This same evening your Secretary and others were rehearsing talks presented the following day at the annual meeting of the Pressure Vessel Research Committee of the Welding Research Council. This streamlined, professionally guided report meeting highlighted ten years of progress of this group and marked the end of several years of service of your Secretary as National Chairman of this activity which now has an annual budget approaching $300,000.

● Chairman Ted Long convened his Exposition Committee in your Secretary's office on September 30th to select a site and date—Apr. 22 to 26 in Philadelphia—for the 1963 Annual Meeting and Welding Exposition. Committee members also completed plans for the Apr. 6-10, 1959, Exposition in Chicago. Space reservations already received indicate that all records will be broken by wide margins.

● Conferences with Past-President Joe Humberstone, now Chairman of Reserve Fund and Headquarters Housing Committees, on October 1st; with First Vice-President Charlie MacGuffie, who is also chairman of the important Technical Council, on October 3rd; and with Treasurer Harry Rockefeller on October 16th, provided your Secretary with most valuable suggestions and guidance covering many SOCIETY activities and industry problems.

● During the evening of October 8th staff member Art Phillips and your Secretary flew to Detroit where they were joined by EAC Chairman Clarence Jackson and I. G. Betts, and then on to Flint, Mich., through a lively electrical storm. Morris Thomas provided transportation from the airport to Hotel Durant where other EAC members had already registered.

● The following day 13 members or guests of your Educational Activities Committee enjoyed the generous hospitality and excellent facilities of General Motors Institute while discussing and planning the many projects now being actively developed by the various subcommittees reporting to this group. In addition to staff members and Chairman Jackson, District Director J. N. Alcock, I. G. Betts, T. E. Jones, G. Leaman, George Luther, R. B. McCauley, H. A. Sosnin, M. D. Thomas, Stan Walter and W. J. Williams were in attendance.

● After the all-day meeting, Messrs. Phillips and Jackson and your Secretary were driven to Saginaw to join Chairman Paul Klain, Secretary George Case and some 85 other officers and members of the Saginaw Valley Section at the High Life Inn where we enjoyed an unusually fine dinner followed by an excellent talk presented by Pittsburgh's Ed Davis. At the conclusion of the meeting Morris Thomas provided transportation for the long drive to Detroit.

● Following a breakfast conference the following morning, President Hoglund chairmanned an all-day meeting of your Board of Directors held in the Hotel Sheraton Cadillac and attended by Past-President Sander, Vice-Presidents MacGuffie and Thomas, and directors from all sections of the country, including Robinson from California, York from Louisana, Pearson from Alabama, Singleton from Missouri, Chouinard from Illinois, Jackson from New Jersey, Miller from New York, Blankenbuehler from Ohio and Alcock from Michigan. Chairman Kendall, Secretary Wolgast and Prof. Wagner of the Detroit Section and M. Thomas of the Saginaw Valley Section were visitors. Staff members included Frank Mooney and Art Phillips in addition to your Secretary.

● A full agenda kept members of the Board busy during a seven-hour period with time out for a luncheon served in the conference room. Actions included the formation of J.A.K. Section with members in the Joliet, Aurora and Kankakie areas near Chicago; establishment of the Oregon Tech Student Section at Klamath Falls, Ore.; a change in name from "Dallas Section" to "North Texas Section" to include both Dallas and Forth Worth; appointment of R. D. Thomas, Sr., as chairman and O. B. J. Fraser and W. Spraragen as members of a special Adams Memorial Committee; election of Dr. R. D. Stout as 1960 Adams Lecturer (Dr. Stout has accepted this outstanding honor and responsibility); adoption of a complete program of activities for the 1959 Fall Meeting in Detroit; consideration of an invitation to establish a welding industry exhibit in the Museum of Science and Industry in Chicago and reference of same to your Manufacturers Committee; preliminary consideration of a group insurance plan for members; discussion of several membership problems and action to liberalize requirements slightly for full members; approval of suggestions to simplify our Bylaws; and establishment of a set of rules of operation for the Board of Directors.

● First Vice-President C. I. MacGuffie, for many years associated with General Electric Co., confirmed that on November 1st he would join the staff of Air Reduction Co.

● During the evening many of the Directors joined members of the Detroit Section at a dinner meeting in Rackham Engineering Building to hear Lovell Lawrence give a coffee talk on "The Evolution of Rocketry and Relationship to Space Travel" and then two short technical talks by W. A. Wilson and J. K. Dawson on "Practical Aspects of Welding Aluminum in Missiles." All three speakers are associated with the Redstone projects. The interesting program also included two color films showing production and launching of missiles. In addition to Chairman Kendall and Secretary Wolgast, Treasurer Stitt, Vice-Chairman Wilcoxson and other section officers and members welcomed the many national officers, directors and staff members who enjoyed this program.

● During the week of October 13th the American Society of Civil Engineers held its annual meeting in New York and your Secretary assisted in several activities. He expects that the Structural Division of this Society will join AWS in sponsoring technical sessions on the welding of structures at one of our meetings during 1960.

● On October 13th the Society lost through death a long-time member associated for many years with Metal and Thermit, and National Electric Welding Machine—Robert L. Browne who held membership card 106 and had recently represented Precision Welder and Flexopress Corp.

● Richard K. Lee presented an excellent discussion on "Iron-Powder, Low-Hydrogen Electrodes" at the October 14th meeting of the New York Section. With Chairman Metterhauser and the vice-chairman unable to attend this meeting Secretary Bellware presided with the able assistance of Stan Walters, H. C. Phelps, J. L. Cahill, J. E. Mooney and other members of the Section.

● Invitations dated October 15th were mailed to all members to participate in the technical program of the 1959 AWS National Fall Meeting to be held in Detroit, September 28–October 1. Each member should carefully review his activities and seriously consider the possibility of taking advantage of this opportunity of benefiting him-

self and others concerned with welded fabrication by organizing and presenting in writing some of his useful welding experiences.

● During the evening of this day your Secretary at home in Stamford, Conn., was surprised and delighted to receive a telephone call from Chairman J. LaBarbera and members of the Shreveport (La.) Section. This was a feature of a national telephone dialing demonstration staged by Bell Telephone as a part of the Section meeting.

● The next day your Secretary conferred with Col. Davies, for many years national secretary of ASME and now coordinator of the plans for the new Engineering Center in New York which will become headquarters for some 15 societies, including AWS, when completed. It is planned to raise funds for this ten million dollar project from the following sources: two million from present facilities; five million from industry ($3\frac{1}{2}$ million already subscribed); three million from the 200,000 members of the societies which will use the new headquarters facilities ($\frac{1}{2}$ million now subscribed). Members of the SOCIETY will be given an opportunity to participate in this important project.

● Technical Secretary Fenton has recently invited manufacturers of electrodes and welding rods to submit information for a new and enlarged edition of the very popular comparison charts. There will be 15 charts covering information on all the newly classified electrodes (E6014, E6018, E6028, etc.) and including the first comprehensive charts on "surfacing" and cast-iron filler metals.

● Editor Rossi plans a number of changes to make THE WELDING JOURNAL more interesting and more valuable to you. Watch for the January 1959 issue. These notes, prepared monthly by your Secretary, will then appear under a new title and masthead.

● Soon after this issue of the JOURNAL reaches you, a ballot on Bylaw changes will be mailed. These changes were discussed in a statement printed in the October issue and the full text with further comments was printed in the November issue. Review these issues again and then mark and return your ballot.

● Following the Board meeting in Detroit, President Hoglund left for the West Coast where he attended a three-day meeting of the Atomic Energy Commission Welding Committee at the Hanford installations in the state of Washington, and joined members of the Portland (October 16th), San Francisco (October 20th) and Santa Clara (October 21st) Sections in their October meetings. Your Secretary met him at New York's Idlewild airport during the evening of October 22nd. After a short night in Stamford we both presented talks at the all-day conference of the New England Sections held in Providence, R. I., on October 23rd.

Fred L. Plummer

Sustaining Membership for Essex Welding

Essex Welding Equipment Co., 17–19 Tichenor Lane, Newark 2, N. J., has been enrolled as a Sustaining Member of the AMERICAN WELDING SOCIETY.

The firm is engaged in the distribution of welding equipment, arc welders, electrodes, accessories, gas welding equipment, welding rod accessories, automatic welding machines, rod, fluxes, welding positioners, turning rolls, manipulators, fixtures, X-ray equipment, supplies, Vacu-Blast equipment, resistance-welding equipment, tip, holders, safety equipment and a complete rental and repair service of welding machines and allied equipment.

Sustaining Member representative is A. C. Axtell.

RESISTANCE WELDING PAPERS

Wanted for

AWS 1959 NATIONAL FALL MEETING

Deadline for Abstracts:

January 15, 1959

Lenco New Sustaining Member

Lenco, Inc., 350 W. Adams St., Jackson, Mo., adds its name to Sustaining Memberships in the AMERICAN WELDING SOCIETY.

Lenco, Inc. was organized in 1948 by Paul J. Leonard under the name of Wagner Manufacturing Co. The firm name was changed to Lenco, Inc., in 1956. This firm is engaged in manufacturing electrode holders, ground clamps and cable terminals under the trade name "HI-AMP." Lenco, Inc. has also done extensive research in high impact and high heat-resistant plastic and operates a division for the custom molding of all types of plastic.

Paul J. Leonard is Sustaining Member representative.

Middlesex Welding New AWS Sustaining Member

Middlesex Welding Supply Co., 1655 Revere Beach Parkway, Everett, Mass., and 2–14 Rindge Ave. Extension, Cambridge, Mass., has acquired Sustaining Membership in the AMERICAN WELDING SOCIETY.

Among the products distributed by the New England firm are: oxygen, acetylene, nitrogen, hydrogen, argon, helium, liquid oxygen and nitrogen, carbon dioxide, propane, and welding and cutting equipment. Other products include: inert-gas-shielded metal- and tungsten-arc welding equipment, automatic welding equipment, manipulators, power turning rolls, fit-up rolls, positioners, surfacing products, silver alloys, arc-welding machines, electrodes and accessories, and safety equipment.

Joseph E. Martin is the Sustaining Member representative.

New Supporting Company from the South

The AMERICAN WELDING SOCIETY announces the enlistment of Yaun Mfg. Co., Inc., 2160 N. 3rd St., Baton Rouge, La., as a Supporting Company member.

The enrollment became effective on Oct. 1, 1958.

• WATCH
• WELDING
• JOURNAL
• JANUARY

EDUCATIONAL ACTIVITIES

Communications Are Essential

The Educational Activities Committee has initiated a newsletter to be issued at frequent intervals for the purpose of transmitting information. The Educational Representative for each of the sections will receive copies and will be charged with the duty of passing this information on to you. Here is a report on some of the projects under way.

Another approach to the communication problem was determined at the Board of Directors meeting in October. In the future all AWS sections will be on the EAC mailing list. This means that the publicity representative of each section will receive news three months before it is published in the technical magazines. Sections will be kept right up to date since the publicity representative will be able to brief members at section meetings on news released during the month.

EAC Meeting

The Educational Activities Committee held an all-day meeting on Oct. 9, 1958, as guests of the General Motors Institute at Flint, Mich. Here is a brief report on some of the projects discussed.

National Meeting, April 1959, Chicago

The subject of the Educational Lecture Series given on April 6th and 7th at 4:30 P.M. will be "Welding for High-Temperature Aircraft Service." The lecturer is Gordon P. Parks, Chief Welding Engineer of Solar Aircraft Co., Des Moines. The interest in this lecture series has been at a high level during the past years with the prospect of continued success.

Standards and Training Recommendations for Vocational Schools

There is a need for some form of guidance in the design and appointment of buildings for the teaching of welding. Course outlines are equally necessary. Fred Plummer met with the AVA Trade and Industry Policy and Planning Committee in August. A committee is being formed to work with the AVA in the preparation of such a manual for vocational schools. The Detroit area is particularly helpful at this stage of the activity.

Boy Scouts Metalworking Manual Committee

A committee has been formed and recommendations will be forthcoming in the near future. "Is" Morrison is chairman of this committee and additional membership is being contacted.

NEMA Booklet

This booklet is designed for engineering students. It contains material on the rudiments of welding and provides students with exercises and problems in welded design. Copy has been completed and it is hoped to distribute this item in the spring.

AWS Section Educational Courses

Many of the AWS sections have programs under way. The EAC would be happy to prepare a manual for guidance of new individuals in the field. In order to prepare such a manual, information is needed. Baton Rouge has been particularly successful and has supplied some details regarding their programs. New York, Chicago, Pittsburgh, Newark, Baltimore, Philadelphia and other sections have experience and a story to tell.

Technical Institute Training

The activity of this committee will be organized by Howard Cary as chairman. This committee will be interested in promoting curricula for welding technicians and associates in welding for one- and two-year post high school training. There is need for a comprehensive survey of the curriculum now being used and the requirements of industry for this type of training.

International Institute of Welding Commission XIV Welding Instruction

Professor M. L. Begeman has reported on the IIW activity at Vienna in July. The meetings were well attended with representatives of between 15 and 20 countries at each meeting. The agenda of the meetings included the following general topics: (1) welding engineers, (2) welding technicians, (3) training of welders and (4) literature for welding instruction.

Educational activities are increasing each season, but the committee needs to hear from more of the sections in order to learn of their needs and also determine if the approach is the right one.

ASME Announces New Officers

Glenn B. Warren, vice president and consulting engineer of the turbine division, General Electric Co., has been elected president of The American Society of Mechanical Engineers.

Elected to serve with Mr. Warren were five vice presidents. They are: Charles H. Coogan, Jr., head of the Mechanical Engineering Department of the University of Connecticut; Gordon R. Hahn, assistant chief mechanical engineer for Gibbs and Hill, New York; John W. Little, president of the Goslin-Birmingham Manufacturing Co., Alabama; Thomas J. Dolan, head of the Department of Theoretical and Applied Mechanics at the University of Illinois; and Harold Grasse, partner in Black and Veatch, Kansas City, Mo.

In addition, Arthur M. Perrin, president of National Conveyors Co., and Richard G. Folsom, president of Rensselaer Polytechnic Institute, were elected directors of the 50,000-member society.

BWRA Elects New Members

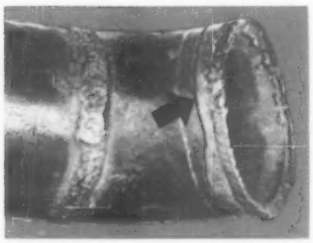
The British Welding Research Association held its annual general meeting on Thursday, September 25th, at which the three following new council members were elected: R. Beeching, the technical director on the main board of Imperial Chemical Industries Ltd.; J. M. Willey, director and general manager of Murex Welding Processes Ltd., Waltham Cross, and T. M. Herbert, the director of research, British Railways Division of the British Transport Commission. J. Strong, this year's president of the Institute of Welding and executive director of British Oxygen Gases Ltd., will represent the institute on the association's council during the year 1958–59.

For details, circle No. 20 on Reader Information Card——>

Watch out for the risks of

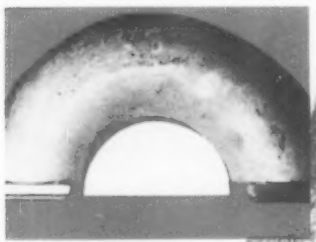
QUESTION MARK FITTINGS!

- *WASTED DOLLARS*
- *PRODUCTION SHUTDOWNS*
- *HAZARDS TO LIFE*
- *DAMAGE TO YOUR REPUTATION*



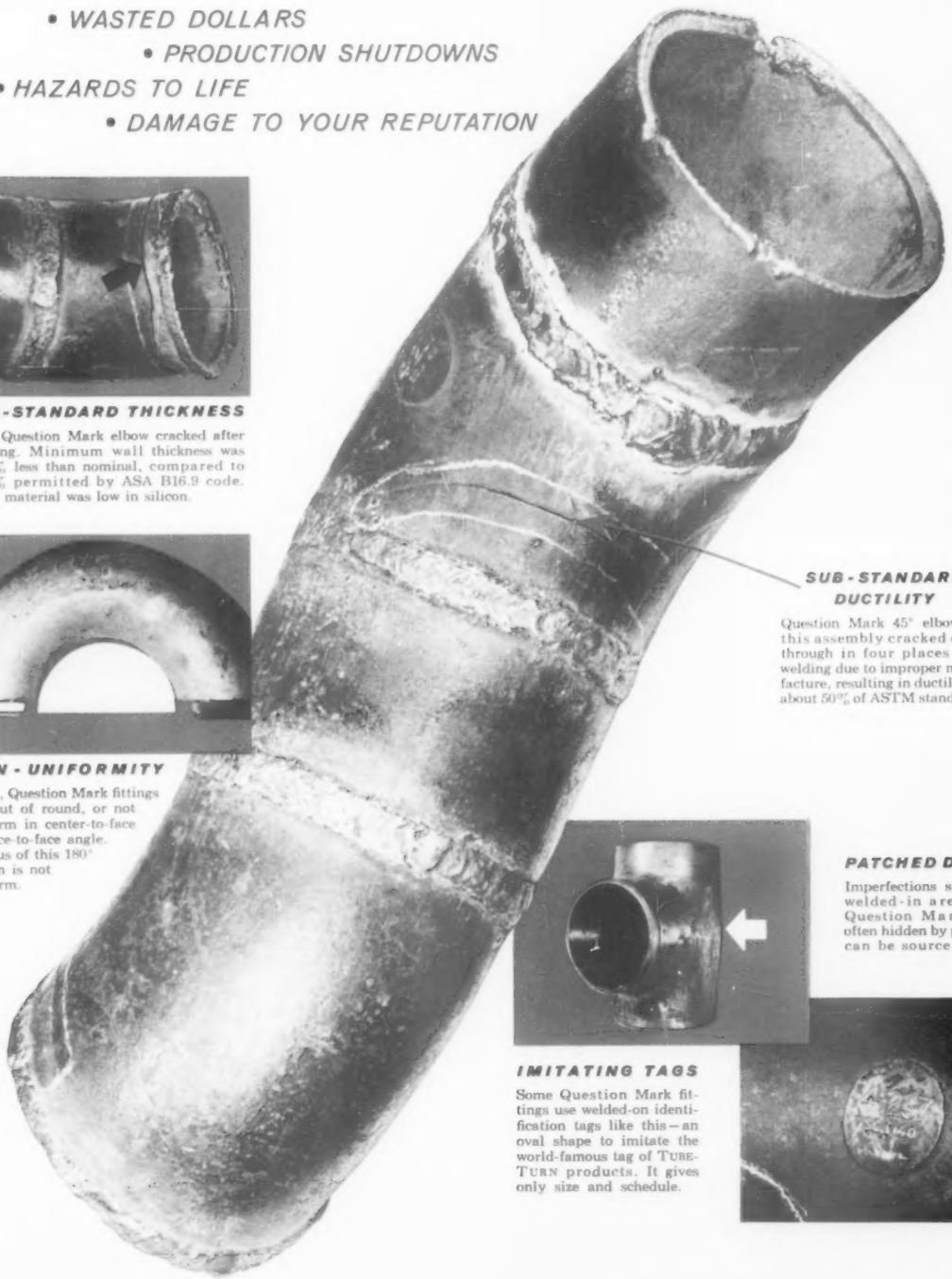
SUB-STANDARD THICKNESS

This Question Mark elbow cracked after welding. Minimum wall thickness was 24.9% less than nominal, compared to 12.5% permitted by ASA B16.9 code. Also, material was low in silicon.



NON-UNIFORMITY

Often, Question Mark fittings are out of round, or not uniform in center-to-face or face-to-face angle. Radius of this 180° return is not uniform.

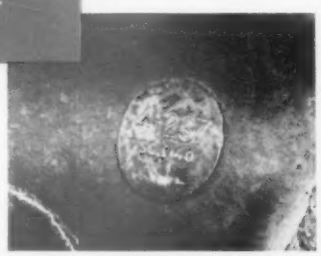


SUB-STANDARD DUCTILITY

Question Mark 45° elbows of this assembly cracked clear through in four places after welding due to improper manufacture, resulting in ductility of about 50% of ASTM standards.

PATCHED DEFECTS

Imperfections such as the welded-in area of this Question Mark tee are often hidden by paint. They can be source of failure.



IMITATING TAGS

Some Question Mark fittings use welded-on identification tags like this—an oval shape to imitate the world-famous tag of TUBE-TURN products. It gives only size and schedule.

A message in the interests of top-quality piping . . . by Tube Turns, Louisville, Kentucky

TO AVOID THESE RISKS . . .

TUBE-TURN *Welding Fittings are completely identified. Information given: Manufacturer's identification, size and wall thickness, material or type number, schedule number or weight, laboratory control number.*

specify and buy top-quality

TUBE-TURN® PRODUCTS

AVAILABLE NEARBY. Your Tube Turns' Distributor gives you prompt delivery from a complete line of more than 12,000 stocked items of TUBE-TURN products. Photo courtesy Central Rubber & Supply Co., Inc., Indianapolis.

"Cheap" Question Mark fittings can be mighty costly in the long run. It pays to safeguard your piping investment, *and your reputation*, by insisting on *known* fittings.

When you specify and buy TUBE-TURN* Fittings and Flanges, you know you are getting unsurpassed quality. They meet all American Standard and Safety Code requirements and are fully and permanently identified for your protection.

The trademarks "TUBE-TURN" and "tt" are applicable only to the quality products of Tube Turns.

*"TUBE-TURN" and "tt" Reg. U. S. Pat. Off.

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CHEMETRON

Section News and Events

as reported to Catherine O'Leary

Arizona

WELDING INFORMATION

Phoenix, Ariz.—The first regular meeting of the season of the *Arizona* Section was held at the HiWay House Motel in the Mt. Vernon Room on September 17th, with twenty members and seven guests present.

After a half-hour executive committee meeting, from 7:00 to 7:30 P.M., a chicken dinner was served.

Chairman John Maffeo opened the business meeting at 8:30 and introduced the new officers for the 1958–59 season. He also explained some of the services of the National Society. In addition, Mr. Maffeo mentioned that technical director Phil Binkley of Consolidated Western Steel Co. had many manuals and booklets on welding problems that are always available to the membership. A twenty-minute color movie on the Delta Home Workshop was shown. The meeting adjourned at 10:00 P.M.

California

MINING FOR NICKEL

Los Angeles, Calif.—The first meeting of the 1958–59 fiscal year for the *Los Angeles* Section was held at the Roger Young Auditorium in Los Angeles on September 8th, with approximately 130 members and guests in attendance. This large turnout for a first season meeting has been attributed to a change in meeting place easily accessible from all outlying districts.

The meeting was opened at 8:00 P.M. with Dave O'Connor, past chairman of the Section, leading the audience in the pledge of allegiance to the flag. This was followed by the introduction of the following past Section chairman: C. P. Sander, 1939–40; S. R. Lanier, 1954–55; Frank R. Drahos, 1953–54; Dave O'Conner, 1957–58 and Al L. Fenlason, 1947–48.

Howard Eubanks, chairman of the Aircraft and Rocketry Panel, spoke briefly on the forthcoming programs to be presented by the Panel. Membership Chairman Leonard Buchanan presented a résumé of membership activities to date.

Entertainment Chairman Bob Waters presented a group of female barber shop quartet singers known as the Sachets, who provided the evening's entertainment.

The program arranged by the vice chairman, Dick Hayes, was a picture in color, "Mining for Nickel," shown by Ken Clark through the courtesy of the International Nickel Co. It was throughly enjoyed by all.

OUTLINES PROGRAMS

Dick Hayes, vice chairman of Los Angeles Section, outlining the impressive technical programs for the forthcoming year at the September 8th meeting of the group

PARTICIPATION IN ASTE CONFERENCE

Los Angeles, Calif.—The *Los Angeles* Section was well represented during the ASTE technical conference

SPEAKERS AT ASTE-AWS TECHNICAL CONFERENCE

C. B. Smith, past chairman of Los Angeles Section introduces AWS participants at ASTE Technical Conference on October 3rd

G. Garfield presents paper on "Tooling for Aircraft and Pressure Vessels" at the afternoon session

W. C. Potthoff speaks on "Ultrasonic Welding Techniques" as part of AWS contribution

←— For details, circle No. 20 on Reader Information Card

held from September 29th through October 3rd at Los Angeles.

Participation by the Los Angeles Section took place on Friday, October 3rd, at which time papers relative to the aircraft and missile industry were presented on welding and joining.

Prominent in the introduction and presentation of these papers were members who have shared in the growth of the Los Angeles Section.

Presiding over the morning session was Mario Ochicano, production design engineer, California Division, Lockheed Aircraft Corp. The Chairman for the afternoon session was C. B. Smith, assistant chief materials and process engineer for the Douglas Aircraft Co., Inc., Long Beach Division.

Two papers were presented at the morning session. One was by Byron Russell, president of the Airline Welding and Eng. Co., and was entitled, "Welding Tooling for Missiles." The second paper dealt with resistance welding and was presented by Henry James of Sciaky Bros., Inc.

Two papers were also presented at the afternoon session. The first, "Tooling for Welded Aircraft and Missile Pressure Vessels," by Gerald Garfield, chief engineer, Research Welding and Eng. Co., Inc., covered the deep drawing of pressure-vessel heads, mechanized methods of welding and inspection. The second paper, presented by W. C. Potthoff, vice president, Aeroprojects Inc., and entitled "Ultrasonic Welding Techniques," covered the various uses of this relatively new process, a description of equipment and its method of function.

WELDMENTS

San Jose, Calif.—Wallace J. Erichsen, manager, Materials Testing Laboratory, Westinghouse Electric Corp., Sunnyvale, Calif., was the guest speaker at the September meeting of the *Santa Clara Valley* Section held in the Hawaiian Gardens in San Jose on September 23rd. His subject was, "Metals Joining in a Heavy Industrial Manufacturing Plant."

Mr. Erichsen gave a very interesting and worth-while talk on problems of large weldments, completely fabricated weldments and cast weldments. These problems were tied in with various metals including T-1 steel, types of welding electrode and welding processes including manual metal arc and inert-gas tungsten-arc.

A chart showed the advantages and disadvantages of weld processes including costs. The slides illustrated various weldments and weld equipment. The slides also showed the large sections of wind tunnels, rotors, and stators that were welded.

Connecticut

VEHICULAR TUNNEL TUBES

Glastonbury, Conn.—The *Hartford* Section held its first meeting of the year at the Villa Maria Restaurant in Glastonbury on September 23rd. Approximately 35 members and guests gathered to hear a talk by Carl R. June, welding engineer, Baldwin-Lima-Hamilton Corp.

SECTION MEETING CALENDAR

DECEMBER 4

IOWA-ILLINOIS Section. American Legion Building, Moline, Ill. Annual Christmas Party.

DECEMBER 5

NORTH CENTRAL OHIO Section. Findlay Country Club. Annual Quiz Program. Howard Cary, Chairman.

DECEMBER 6

FOX VALLEY Section. 6:00 P.M. Menasha Elks Club. Christmas Dinner-Dance.

DECEMBER 8

NORTHWEST Section. Minneapolis, Minn. "Progress and Development of Welding Processes and Applications," C. E. Jackson.

DECEMBER 9

DAYTON Section. Kuntz Cafe, Dayton, Ohio. Social 6:30 P.M. Dinner 7:00. Meeting 8:00. Speaker: William Chase, General Motors Technical Institute.

NEW YORK Section. Victors Restaurant, New York City. Sustaining Members' Night. "What the Future Holds for Welding." Panelists: President G. O. Hoglund; Past-President Joseph Humberstone; National Secretary Fred Plummer; Dave Brown, President, American Bureau of Shipping.

DECEMBER 11

MADISON SECTION. Madison, Wis. Eagles Club. "Techniques and Equipment for Manufacturing Welded Products," John Mikulak, Worthington Corp.

NIAGARA FRONTIER Section. LaSalle Yacht Club, Niagara Falls, N. Y. Dinner 6:30 P.M. Meeting 8:00. "Welding Procedures in an Incentive Application," Harold Baldwin, LeTourneau Westinghouse Co.

OKLAHOMA CITY Section. Dodson Cafeteria. Speaker: Richard J. McGinn, Nelson Stud Welding Co.

PUGET SOUND Section. Engineers Club, Seattle, Washington. "Position Welding—A Step Toward Automation," Paul Galton, Worthington Corp.

DECEMBER 12

CHICAGO Section. Annual Christmas Party. Informal Dinner-Dance. Martinique Restaurant, Evergreen Park, Ill.

INDIANA Section. Dinner 6:30 P.M. Home Talent Night. New AWS Film and 20-minute talks by Bill Jones, General Electric, and Gene Wiley, Delco, Radio Div., GMC.

MILWAUKEE Section. 6:30 P.M. Ambassador Hotel, Milwaukee, Wis. "Future Use of Resistance Welding Controls," Stuart Rockafellow, Robotron Corp.

DECEMBER 15

PHILADELPHIA Section. Naval Architects Night. Engineers Club. 8:00 P.M. "Design and Construction of Nuclear Power Plants for Ship Propulsion," R. P. Goodwin, Maritime Administration.

DECEMBER 16

HOLSTON VALLEY Section. Kingsport, Tenn. "General Welding and Fabrication of Stainless Steel," J. A. Goodford, Crucible Steel Co.

NEW JERSEY Section. Essex House, Newark, N. J. Dinner 6:30 P.M. Meeting 8:00 P.M. "Welding Dissimilar Metals," K. M. Spicer, International Nickel Co.

NEW ORLEANS Section. "Metallurgical Problems of Atomic-Powered Vessels," T. A. Dawson, Ingalls Shipbuilding Corp.

DECEMBER 18

BATON ROUGE Section. Dinner 7:00 P.M. "Metallizing and Its Practical Applications," Emil J. Dalbo, Metallizing Eng. Co.

DECEMBER 19

SAN FRANCISCO Section. Christmas Dinner-Dance. Mira Vista Country Club, El Cerrito, Calif.

DECEMBER 20

IOWA Section. Dinner Dance. Hotel Kirkwood ballroom. 7:00 P.M. Cocktail hour 6:00-7:00.

Editor's Note: Notices for March 1959 meetings must reach Journal office prior to December 20, so that they may be published in February Calendar. Give full information concerning time, place, topic and speaker for each meeting.

PANEL DISCUSSION HELD BY CHICAGO SECTION

The September 19th meeting of the Chicago Section featured a Panel Discussion on "How to Use Natural Gas for Metal Cutting and Preheating." The speakers on the Panel are shown above

Among the honored guests in the audience were National Secretary Fred L. Plummer, L. C. Monroe, Assistant National Secretary Frank J. Mooney and District Director A. F. Chouinard

Mr. June's talk concerned the building of one of the largest underwater vehicular, trench-type tunnels in the world. A new concept in the design, fabrication, assembly and launching of tunnel tubes was employed. The talk described the fabrication methods, equipment, launching and final assembly of the tubes. Mr. June presented his talk in a fine informal manner, illustrating with slides, and answering questions.

The role of coffee speaker was handled very nicely by an honored guest, Clarence E. Jackson, chairman of the Educational Activities Committee, who spoke on his committee's many and varied activities.

Florida

WELDING ELECTRODES

Miami, Fla.—The *South Florida* Section held a dinner meeting at the Ocean Ranch Hotel in Miami on September 17th with 25 members and guests attending.

Guest speaker A. Clemens, Jr., director of research and welding engineering of Arcrods Corp. began his talk by stating that, fortunately for the electrode manufacturers, no one has yet discovered the truly universal electrode. But since the "end use requirement" determines the selection of the electrode, little hope can be held by the consumer of ever reaching the goal.

Mr. Clemens described, with the aid of slides, how the various ingredients composing the electrode coating affect the deposition of weld metal. He described the purpose of each of the dozen or more compounds employed to fulfill the "end use requirement."

Illinois

PANEL DISCUSSION

Chicago, Ill.—A panel discussion on "How to Use Natural Gas for Metal Cutting and Preheating" was the subject of the September 19th meeting of the *Chicago* Section held in the Auditorium of the Peoples Gas Light & Coke Co. Dinner preceded the meeting at Milner's Restaurant.

Five speakers spoke on topics related to one general subject for approximately fifteen minutes each. They were as follows: G. R. Spies, Air Reduction Sales—Equipment Used with Natural Gas; A. G. Barkow, Natural Gas Pipe Line Co.—Definition and Origin of Natural Gas; R. A. Himmelmann, Peoples Gas Light & Coke Co.—Distribution, Code Requirements; J. R. Kelly, Harris Calorific Co.—General Uses, Advantages and Disadvantages; and J. A. Hudson, Linde Co.—Comparative Economy with Other Gases.

Prior to the technical meeting, National Secretary Fred L. Plummer addressed the group, advising that he and Assistant Secretary F. J. Mooney had spent the afternoon meeting with the Chicago Arrangements Committee in preparation for the Society's 40th Annual Meeting and Welding Exposition to take place in Chicago, April 6–10, 1959. He stated that the Committee, chairmanned by L. S. McPhee of the Whiting Corp. is now in the process of developing the program to insure its success. He also expressed his appreciation to the Chicago members and guests and advised that maximum manpower will be needed from the Section toward the end of conducting a successful meeting next April.

Following the close of the technical meeting, a film on "Welding America" was shown in color. It was well received by the audience.

WELDING ELECTRODES

Chicago, Ill.—Guest speaker H. F. Reid, Jr., of the McKay Co., treated the *Chicago* Section at their October 17th meeting, to a highly interesting talk on evolution of welding electrode coding and classification.

The unusual title of Mr. Reid's talk, "It Isn't Mud," originated from a personal experience in which a curious electrode user closely examined a covered electrode and inquired, "What kind of mud is used to coat electrodes?" Mr. Reid's talk was effectively supplemented by slides, the combination of which proved most informative to approximately 100 members and guests present.

Preceding the scheduled meeting, a color film "Steel Spans the Chesapeake" was shown through the courtesy of the Bethlehem Steel Co.

Of particular interest to Chicago Section members is the announcement that their 4th Annual Christmas Party is planned for December 12th at the new Martinique Restaurant in Chicago. The complete sellout of last year's party is an indication of the enjoyable time had by all and this year's party will be no exception.

ALLOY STEEL

Peoria, Ill.—A meeting of the *Peoria* Section was held on September 17th at which time a talk on "NAXtra 90 Steel" was given by C. L. Altenberger, technical assistant to the president of Great Lakes Steel Corp.

DISCUSSES WELDING OF ALLOY STEEL

C. L. Altenberger spoke on the welding of alloy steel at the September 17th meeting of the Peoria Section. Shown (*left to right*) are H. D. Smith, T. H. Spencer, Mr. Altenberger and Section Chairman A. Schlis

Indiana

DINNER DANCE

Indianapolis, Ind.—The September meeting of the *Indiana* Section held on September 26th was the annual Ladies Night dinner dance for members, their wives and guests.

The dinner was held at the Roof Garden of the Hotel Severin, Indianapolis, and thirty-two people attended. There were corsages for the ladies and numerous door prizes.

Music for the dance was provided by "Chuck" Baldwin and his six-piece band.

NATURAL-GAS CUTTING

South Bend, Ind.—The *Michiana* Section opened their 1958-59 season on September 18th when almost forty members and guests gathered to hear a very interesting discussion of "Natural-Gas Cutting" by G. R. Spies, equipment engineer, Development Dept., Air Reduction Co., Union, N. J. Mr. Spies discussed the nature of natural-gas heating properties and how they compared to acetylene. Differences in equipment and techniques were pointed out. Costs were discussed and applications where natural gas can do a job for less money were suggested. It was a most interesting and informative talk.

Iowa

ALUMINUM WELDING

Des Moines, Iowa—The first meeting of the *Iowa* Section of the year was held September 18th in the Garden Room of the Kirkwood Hotel. The dinner was a buffet style and excellent. Speaker was George W. Frehafer of the Reynolds Metals Co., Richmond, Va.

Mr. Frehafer's lecture on "Welding, Cutting and General Fabrication of Aluminum" covered many interesting and important details dating back to 1886. Some of the major developments in the welding of aluminum mentioned by Mr. Frehafer were: first welding of aluminum by the Swiss in 1907; welding with flux 1911; flux-coated electrodes 1927; resistance welding 1930; inert-gas-shielded welding 1950; and the most recent development in the fabrication of aluminum, the process of arc cutting in 1955.

The cutting of aluminum by the tungsten-arc process was discussed in detail by the guest speaker. Mr. Frehafer said that the open-circuit voltage should be at least 90 to 100 volts, and the gas mixture 80% argon and 20% hydrogen. The cutting speeds for one-quarter-inch thick aluminum is near 300 ipm at 70 v and a gas flow of 60 cfh. For one-inch-thick aluminum, cutting speed is 20 ipm at 70 v and a gas flow of 60 cfh. He mentioned that, when cutting thick material, it is best to drill a hole first.

Mr. Frehafer said that, in the manual welding of aluminum, helium is the best shielding gas to use. The reasons for this are higher arc voltage, better shield, more heat released, and, while material is in molten state, helium keeps it from re-oxidizing. Argon gas tends to produce more porosity.

This was a very interesting and informative talk.

Kansas

HEAT-RESISTANT ALLOYS

Wichita, Kan.—The Westinghouse Electric Corp. provided an excellent speaker, F. D. Seaman of Kansas City, for the October 13 meeting of the *Wichita* Section held at the Branding Iron Restaurant.

Mr. Seaman's subject was "The Effect of Jet Engineering Operation on Welding Design and Manufacture." His experiments with and comments on welding the high heat-resistant alloys were very interesting. This is a new field in welding which requires a greater understanding in metallurgy than before.

The dinner and meeting were preceded by a popular social hour.

Louisiana

PLANT TOUR

Baton Rouge, La.—On June 5th approximately thirty-five members of the *Baton Rouge* Section made a tour to the plant of the Southwest Fabricators at Morgan City, La. They were accompanied on the trip by Opie Shelton, executive secretary of the Baton Rouge Chamber of Commerce.

Bill Bailey, superintendent of the Southwest Fabricators, was a most gracious host. After a ninety-mile trip in air-conditioned, T-V equipped busses, Mr. Bailey conducted the party through the fabrication yards and explained the work under way. Their largest job was the fabrication and erection of "Islands" for a large sulfur company. These structures, some weighing as much as five hundred tons, are completely assembled and welded in the fabrication yards at Morgan City, loaded on barges and towed to a location seven and one-half miles off the Louisiana coast in the Gulf of Mexico, where they are placed in position in about 90 ft of water by large barge derricks. Southwest Fabricators have one derrick of 750 tons capacity, two of 500 tons, and several of 250 tons. These "islands" will then be connected by 15-ft wide roadways, all welded, and will become the drilling platforms, living quarters, maintenance shops and helicopter landing platforms for the development of a new sulfur dome.

Probably the most interesting phase of the tour was the enormous amount of aluminum fabrication being done. Drilling platforms, 120 ft high with 30-in. diam legs, are completely fabricated from $^3/_8$-in. thick aluminum plate and pipe. After assembly and welding, the finished structures are loaded on barges and towed to Lake Maracaibo, Venezuela, where they are placed in position in the brackish waters of the lake where steel would soon deteriorate.

Another "first" for Southwest Fabricators is the fabrication of several large tanks about 50 ft square of $^3/_4$-in. aluminum plate and designed

to fit into the hull of a vessel where they will be insulated and refrigerated and used to haul liquified gas to European markets.

Coffee was served to the group in the stainless-steel, all-welded galley of one of the company's new 500-ton barge derricks. The trip back to Baton Rouge was marked by a stop at Cypress Inn for a chicken and frog-legs dinner.

ALUMINUM WELDING

Baton Rouge, La.—Sixty-three members and guests of the *Baton Rouge* Section attended the first meeting of the season on September 18th at Bob and Jake's Steak House.

Following cocktails and a steak dinner, the coffee speaker, Justin Wilson, a Baton Rouge industrial safety consultant, drew on a seemingly inexhaustible fund of "Cajun" stories to entertain the guests, but managed to slip in some very timely comments on welding safety and housekeeping between stories. Mr. Wilson stressed the direct connection between good housekeeping and safety, saying "a clean, uncluttered welding job is the job with the best safety record."

The technical speaker of the evening was Fred Wilson, New Orleans district manager of Air Reduction Sales Co., who spoke on Aluminum Welding and Cutting." Mr. Wilson's timely talk was illustrated with a short film and was well received.

Maryland

OXYGEN CUTTING

Baltimore, Md.—A very interesting meeting was held on October 17th by the *Maryland* Section at the Engineers Club in Baltimore. The Section was fortunate to have Hugh Justice of the Martin Co. show a film on the Matador-type Missile.

The main speaker, G. R. Spies of the Air Reduction Co., Union, N. J., gave a very comprehensive talk on "Propane and Natural Gas Cutting." It was quite interesting as everyone has been open to the arguments of propane vs. acetylene for cutting. After the talk there were quite a few questions put to Mr. Spies and they were answered to everyone's satisfaction. A good deal of information was gathered from this talk.

TOUR OF INSPECTION

Sparrows Point, Md.—The *Maryland* Section, as has been the custom, opened the season with a trip. This year they were the guests of the Bethlehem Steel Co. and made a tour of inspection of their plant at Sparrows Point, the biggest steel plant in the world.

Two hundred and forty-five members and guests gathered at the Sparrows Point Country Club at 9 A.M. on September 20th, and filled a caravan of six buses. Headed by the chief of the plant police, they proceeded to and through the plant area for a full four hours. Then they went back to the Country Club for liquid refreshment, on a Dutch-treat basis, and for a very fine dinner at the delightful Club House.

This was, without a doubt, the best trip the Maryland Section has ever made.

Massachusetts

WELDED STRUCTURES

Worcester, Mass.—The first meeting of the current season of the *Worcester* Section was held on October 6th at the Tower House. This was a joint meeting with the local chapter of the American Society of Civil Engineers. Following a social get together, dinner for 56 was served at 7:15 P.M. with a few others coming in later.

The speaker of the evening was Van Rensselaer P. Saxe, whose subject was "Welded Structures."

As a consulting engineer, Mr. Saxe has pioneered ever since 1926 on this subject. Many of the present-day welding procedures that are taken for granted by many architects, contractors, steel fabricators and real estate operators, are the result of his painstaking efforts to find the right values, and methods, and have them written into specifications and building codes. To further facilitate and simplify the use of welded joints in large hospitals, auditoriums, and office buildings, his office has published a book showing a large number of joint illustrations and formulas by which each can be evaluated.

Mr. Saxe showed pictures of structures, some dating back over thirty years. On many of these structures, he quoted the amount of steel tonnage that welding, as a joint connection, was able to make available for other uses. The dollar value usually amounted to a substantial sum of money. Many of these buildings have since withstood hurricanes and a few have even survived earthquakes. The pictures shown in the course of this lecture amounted to a visual history of the evolution of welding in the construction of large buildings, and to a lesser extent to its adoption by the engineers charged with the building of railroad and highway bridges.

Mr. Saxe addressed the Worcester Section some six or seven years ago and the members were very grateful that he had been able to arrange his busy schedule at this time so that he could meet with them again.

Michigan

PLANT TOUR

Grand Rapids, Mich.—The *Western Michigan* Section held its first fall meeting with dinner on September 22nd at the Varsity Grille in Grand Rapids and an inplant demonstration at the Kirkhof Mfg. Co. of the same city.

There were 60 members and guests

SAXE DISCUSSES WELDED STRUCTURES

Van Rensselaer P. Saxe was the guest speaker at the October 6th meeting co-sponsored by the Worcester Section of AWS and by the local chapter of the American Society of Civil Engineers. (*left to right*) front row, are R. L. Childs, A. E. Carey, W. H. Frye, Mr. Saxe and K. F. Clarke. Standing are E. W. Spellman, C. H. Murray and E. C. Hall. Mr. Carey represented ASCE

present for the dinner at the Grille, and these were joined by nine more for the plant demonstrations and tour.

There were also two films on resistance welding, one produced by the Kirkhof Co. and another by the Resistance Welder Manufacturers Association. Both were of excellent quality. The group was then shown through the vast plant of the Kirkhof Co. and shown the various processes in making resistance-welding machine parts and special setups for resistance welding.

Much interest was shown in this first meeting, as well as interest in the Section's activities, by prospective members.

Missouri

METAL-JOINING PROCESSES

Kansas City, Mo.—"The Application of Metal-Joining Processes to Jet Engines" was the subject of a talk given by F. D. Seaman, section engineer, Materials Laboratory & Process Development Section, Westinghouse Electric Corp., at the October 9th meeting of the *Kansas City* Section held in the World War II Memorial Building.

Mr. Seaman discussed the interrelationship of the joining processes and materials used in the fabrication of engine components. Included were the metallurgical, design and practical aspects of jet engine construction.

PLANT AND YARD TOURS

St. Louis, Mo.—The *St. Louis* Section conducted a special tour of the facilities of the St. Louis Shipbuilding & Steel Co., on Thursday evening, September 25th. Due to the large attendance of 175, two tours were scheduled; one beginning at 7:00 P.M. and the other at 8:30 P.M. The visitors were conducted in small groups of ten each to permit easier handling and closer attention to questions.

Several items of special interest were viewed. The Yard now has in operation a new large steel uncoiler which unrolls and straightens huge coils of steel plate up to $\frac{1}{2}$ in. thick.

Recent installations of special automatic submerged-arc welding apparatus were demonstrated. These included multiple-head and multiple-wire operations. Special flame-cutting and automatic serrating equipment were viewed in operation. After looking over subassembly fabrication areas, each party was conducted to the company's extensive barge production jigs where they could witness the assembly of pre-fabricated component and the operation of the Yard's huge side-member positioners. A completed barge was also available for inspection.

In the wheel shop, propellers in various stages of fabrication demonstrated St. Louis Ship's unique methods of welding flukes to hubs to provide any desired pitch. Samples of all types of propellers were displayed.

The recently launched towboat M/V "United States," which is in the water for final fitting, was one of the prime items of interest during the tour. Built for the Federal Barge Lines, the huge 4-screw, 8500-hp, 180-x 58-ft towboat is the largest and most powerful of its kind on the inland waterways and provided an excellent measure of the Yard's engineering and productive abilities.

Another smaller towboat, the M/V "Etta Kelce," being built for Mid American Towing Co., was on the ways and partially fabricated.

At the conclusion of the tours, the parties assembled in the spacious new office building where they were treated to refreshments and greeted by St. Louis Shipbuilding's President, Art Parsons. Mr. Parsons and Peter C. Enslin, Engineer, provided the answers during an informal question period, which developed over the coffee cups.

STRUCTURAL WELDING

St. Louis, Mo.—The October meeting of the *St. Louis* Section held on October 9th was addressed by Dr. Wayne Teng, chief structural engineer, John F. Meissner Engineers, Inc., Chicago, Ill.

Dr. Teng gave a review of recent developments and applications in structural engineering, new techniques, new materials and new problems that confront structural engineers. Emphasis was placed on application of structural welding.

Dr. Teng's talk was beautifully illustrated with colored slides and he exhibited an excellent command of his subject. His material was fresh, informative and interesting. Among the projects discussed were his work in connection with the design and erection of the Air Force Academy in Colorado Springs, Colo., and the Inland Steel Building in Chicago. Design innovations, which come about through the use of aluminum, T-1 steel and other structural materials were reviewed. He reported on the number of staggering design problems which engineers must solve. IBM computers are often employed to shorten design time. Comparative figures were presented demonstrating relative costs of welded, riveted and bolted structural joints.

NEW JERSEY SECTION HEARS JACKSON ON WELDING ABROAD

Some of the members and guests who attended the pre-meeting dinner of the New Jersey Section on September 16th

C.E. Jackson, the guest speaker, reported on "Developments in Welding Abroad"

New Jersey

WELDING ABROAD

Newark, N. J.—Clarence E. Jackson, staff engineer of the Linde Co., was the guest speaker at the first of the season's regular monthly dinner meetings of the *New Jersey* Section held at the Essex House in Newark on September 16th.

After an excellent dinner and the showing of a technical film entitled "Inert Arc Welding of Carbon Steel Pipe," through the courtesy of the Linde Co., over one hundred members and guests settled down to hear Mr. Jackson talk on "Developments in Welding Abroad." Mr. Jackson first gave a brief summary of the activities of the national headquarters on education, giving emphasis to the fact that education is the key to our survival. Also, he mentioned that shortly a brochure will be published entitled "Opportunities in Welding."

With the aid of color slides, he conducted his audience through a tour of industrial plants in England, Holland, Belgium and Germany, describing and comparing methods of welding techniques with those of which we are familiar. Excellent color pictures were shown of the welded structural members of the "Atomium" at the Brussels International Fair in Belgium.

New Mexico

FIELD TRIP

Belen, N. Mex.—The first program of the season of the *Albuquerque* Section, held on Thursday, September 11th, was arranged by J. J. Flowers, representing the Santa Fe Railroad. The meeting was a demonstration type, held south of Belen, N. Mex. on the Santa Fe Railroad where they are welding railroad rails into very long lengths. The equipment is known as the "Schlatter Flash-Butt Welder" and is housed in four special-built railroad cars.

It was very interesting to note the progress made in joining such heavy rails, which will stand stress under all weather conditions, into lengths of a quarter of a mile.

It was noted that the Santa Fe Railroad is continuing to expand its program utilizing the flash-welding method for fabricating continuous welded rail. The program was first begun in New Mexico and later spread to other parts of the system.

Developed in Switzerland and known as the Matisa-Schlatter electric unit welding process, the new and improved technique is being used at Belen to weld about 41 miles of new rail for relaying on stretches of the main lines in New Mexico this year. By the end of 1958, Santa Fe will have laid 811.8 miles on the system, and will have laid 222.7 miles in New Mexico alone by the end of 1959.

The Matisa machine has a maximum capacity of about 15 welds per hr. From a stockpile of 39-ft rails, the rail is fed into the welding unit and becomes one continuous length of 1440 ft. The finished products are then fed directly onto a train of 31 flat cars, having a capacity of 12 strings of continuous rail. The rail then is hauled to the site where it will be laid.

The advantages include a smoother ride for the passenger, and maintenance costs to the railroad are substantially reduced.

The Santa Fe officials pointed out that the method was adopted after a great deal of engineering and the outlay of substantial capital costs.

New York

PRESIDENT HOGLUND PRESENTS AWARD

Buffalo, N. Y.—Seventy-five members of the *Niagara Frontier* Section met at the Cypress Inn on September 25th to partake in a meeting of unusual interest.

National President G. O. Hoglund presented a Meritorious Certificate Award to Is Morrison, Chairman of the executive board of Morrison Steel Products, a long-time and active member of the American Welding Society. Also on hand to honor Mr. Morrison were Director-at-large Clarence E. Jackson, the principal speaker of the evening, and Harry E. Miller, District #3 Director. A former member of the Board of Directors, Mr. Morrison also served as chairman of such national committees as Technical Council, Manufacturers and Membership.

The meeting was concluded by a discussion by Clarence Jackson on the promotional work of the Educational Activities Committee. Mr. Jackson also reported on his recent trip to England.

MORRISON RECEIVES NATIONAL AWARD

Pipe in hand, Is Morrison receives his Meritorious Certificate Award from President Hoglund at the September 25th meeting of the Niagara Frontier Section in Buffalo, N. Y. Participating in the ceremony are (*left to right*) Ralph V. Voight, chairman of the Niagara Frontier Section; President Hoglund; Mr. Morrison; Harry E. Miller, Director of District #3; and Director-at-Large Clarence E. Jackson

APPRENTICE CONTEST

New York, N. Y.—The Fifth Annual New York State Apprentice Contest was held during the month of July and awards were given to the winners. These awards have been presented by the *New York* Section of the AWS. The first recipient was Richard Huber of the Steamfitters' Local Union #638, New York City, for being the outstanding steamfitter and plumber in the State.

The second recipient was Warren Weltsch of the Plumbers' Local #1 in Brooklyn, for being the outstanding plumber and steamfitter-apprentice in the State.

James Day, Jr., of Steamfitters' Local Union #543, Yonkers, N. Y.; and John Capabianco of Plumbers' Local Union #2 of New York City, placed second in the Apprentice Contest, and also received awards.

WIN FIFTH ANNUAL NEW YORK STATE APPRENTICE CONTEST

R. Huber (*left*) winner of Fifth Annual New York State Apprentice contest receives his award from Richard Walsh, Apprentice Coordinator of the Eastern States. He was named the outstanding steamfitter and plumber in the State

Warren Weltsch (*left*) receiving his award as the outstanding plumber and steamfitter apprentice in the State. Awards were given by the New York Section of AWS

James Day (*left*) and John Capabianco (*center*) placed second in the contest which was concluded on July 11, 1958 in New York City. They are shown receiving their awards

It is gratifying to note the development of these young men. Through their own efforts, they are becoming outstanding members in their profession.

WELDING ABROAD

New York, N. Y.—The first meeting of the 1958–59 season of the *New York* Section was held on Sept. 9, 1958, at the Victor Restaurant, 1 East 35th St., where an excellent dinner was served prior to the meeting.

The speaker of the evening was Clarance E. Jackson, staff engineer of the Newark Development Laboratory of the Linde Co. Originally, Bela Ronay had been scheduled to speak. However, since Mr. Ronay was unable to attend, Mr. Jackson had kindly made himself available.

The subject of the evening was "Development in Welding Abroad." This topic proved to be very interesting as Mr. Jackson had spent over three months in England, Belgium, Holland and Germany on special assignments in welding. The discussion consisted of a comparison of the welding methods, equipment and operators in Europe as of those in the United States. Mr. Jackson stated that the same welding methods are being used, but the majority of the equipment was generally not as modern as in this country. Skilled operators are producing quality weldments but, as far as the equipment and safety are concerned, the responsibility rests with the operator rather than with the employer.

Mr. Jackson's discussion was illustrated by many colored slides taken during the trip. Especially interesting were the slides taken of the Brussell's World's Fair which included many welded structures and welding aspects of the World's Fair.

The meeting turned out to be an interesting one and a capacity audience attended.

North Carolina

SURFACING

Raleigh, N. C.—The regular meeting of the *Carolina* Section was held in the Colonial Room of the S & W Cafeteria, Raleigh, on September 29th.

Harry V. Kough, marketing manager for Coast Metals, Inc., spoke on "Hard Surfacing, Its Characteristics, Application and Methods." The talk was accompanied by slides. This subject was interesting and informative. Mr. Kough answered questions from the floor on problems encountered with the hard surfacing of various types of equipment.

Ohio

WELDING ELECTRODES

Cincinnati, Ohio.—Jerry Hinkel, electrode application engineer of Lincoln Electric Co., Cleveland, Ohio, was the honored speaker at the October 28 meeting of the *Cincinnati* Section held in the Engineering Society of Cincinnati Headquarters. His wealth of knowledge and vast experience maintained an exciting interest as he discussed the "Selection and Application of Welding Electrodes."

PLANT TOUR

Cincinnati, Ohio.—Bob Losee, newly elected *Cincinnati* Section Chairman, has been working diligently with his new Executive Committee to increase attendance with more interesting programs and add to the Section membership.

The September meeting opened the Section's fall program with an informal dinner at the Frontier Restaurant and a plant tour of the Walter C. Beckjord Power Station. This power station is one of the most modern and efficient power stations in the Cincinnati area.

The tour included the inspection of generating equipment, the power system (which covered boilers and water-purification system for same), mechanical controls and electrical controls of the power station.

WELDING OF T-1 STEEL

Cleveland, Ohio.—The *Cleveland* Section started its new year in new headquarters. Through the interest of individuals, companies and technical societies, Cleveland has a new, modern "Engineering and Scientific Center." The large, well-equipped building, with separate parking facilities, is to be the center of all technical activities in the community and the Cleveland Section, starting with the October meeting, will hold all its meetings here. The excellent social, dining and meeting rooms are expected to add considerable attraction to local activities.

The October meeting was the first for the new set of officers: Harry E.

WELDING OF T-1 STEEL COVERED BY KEAY

Technical speaker for Cleveland Section's October 8th meeting, Louis Keay, and Mike Shane, Technical Chairman, "bone-up" on T-1 steel

Bill Metzger (*left*) and Harry McBridge, Section Chairman, look over the schedule of technical sessions to be held this year by the Cleveland Section

McBride, chairman; Thomas L. Dempsey, first vice chairman and responsible for the technical sessions; Irving E. Schreck, second vice chairman who, as part of his other duties, will arrange for the Spring Symposium; and R. W. Metzger, Jr., secretary and treasurer.

Technical speaker for the October meeting was Louis K. Keay, technical service engineer, Lukens Steel Co. His subject was "Fabrication and Welding of T-1 Steel." He discussed the metallurgy of the steel, its heat treatment and properties and how these affect fabricating operations, such as forming, and particularly welding. T-1 was compared to other types of steel and the precautions indicated in welding with various processes.

WELDED DESIGN

Warren, Ohio.—A very gratifying attendance of 50 members and guests were on hand to hear John Mikulak of Worthington Corp. present an excellent talk on "Product Design for Welding" at the October 16th dinner meeting of the *Mahoning Valley* Section held at the El Rio Restaurant in Warren.

Prior to the main program, Chairman Forrest Johnson announced that the Section would again sponsor an Educational Program next spring. The tentative subject for this year's program will be "Fundamentals of Arc Welding."

Mr. Mikulak's ninety-minute presentation covered functional design of parts with consideration for economics, available equipment, strength and the use of composite designs for assemblies employing castings, forgings, etc. with plates and shapes. Automatic and semiautomatic welding with respect to joint configuration and thermal capacity were also covered. A discussion of the press brake and its use for bending was made along with ways of obtaining the correct geometry for fitup of various shaped parts. Finally, the thought of designing fabrications with automation in mind was discussed considering decreased costs and distortion, and increased efficiency.

IRON-POWDER ELECTRODES

Reedurban, Ohio.—It was a good day when *Stark Central* Section had Don Howard of ACF Industries address its members. In December 1957, he did not make it, as he was snowbound at Newark, N. J.

This time, September 10th, he did make it. Having passed the "Dinner Test" (Smörgåsbord) successfully at the Towne and Country Restaurant in Reedurban, Mr. Howard launched into a description of his company's experiences with the iron-powder covered electrode from its introduction in 1953 through its present recommended uses. His report covered actual applications, as well as test results vs. manufacturers' claims. His recorded and interpreted results were well worth noting, for, as he put it, "the powdered-iron electrode is here to stay, but be sure you find and use the right one." His related anecdotes on vendors, practical testing, and on-the-road tales, provided a fast 45-min program.

Mr. Howard is, of course, a director-at-large of AWS.

MULLER SPEAKS ON WELDING ENGINEERING

Albert Muller was guest speaker at the September 15th meeting of Philadelphia Section. Left to right are F. Iapalucci, Walter Wooding, Dr. Muller, 1st National Vice President Chas. MacGuffie and Chas. Dooley

Dr. Muller delivering his talk on "Welding Engineering" before an audience of over 100 members and guests

Pennsylvania

TITANIUM WELDING

Erie, Pa.—The *Northwestern Pennsylvania* Section met for dinner and meeting on September 16th at the Town & Country Restaurant in Erie. D. A. Wruck of the Titanium Metals Corp. of America, New York, N. Y., presented a slide-illustrated talk on welding of titanium.

WELDING ENGINEERING

Philadelphia, Pa. — Fifty-seven members and guests of the *Philadelphia* Section met for dinner at Cavanaughs Restaurant on September 15th. Among those present were National Secretary Fred Plummer, Charles MacGuffie, 1st National Vice President and Educational Committee Chairman Clarence Jackson.

Also present were Dean Kenneth Riddle and Dean Lawrence Barden of Drexel Institute, and Prof. George Head of the Department of Metallurgy at Drexel.

Coffee speaker was C. Lupton, personnel manager of Lansdale Tube Co. The subject of his talk was "A Knock on the Door." Mr. Lupton delved into the necessity of young men making the right decision when choosing their profession. He explained the function of a national organization, The Jets, in helping these students. Mr. Lupton emphasized the fact that the responsibility of education lies with the local groups.

Immediately after Mr. Lupton's lecture, the group went to the Drexel Institute Auditorium where Albert Muller, assistant to the president of Air Reduction Sales Co., New York, spoke on "Welding Engineering." Dr. Muller skillfully traced the history of welding from the ancient art of the operator to the modern science of the welding engineer. He clearly demonstrated, with slides and films, the breadth of application and the growth of the welding engineer into a full fledged and complex profession having a great need for people who are not at present available.

PANEL DISCUSSION

Philadelphia, Pa.—A. C. Young, Panel Discussion Chairman of the *Philadelphia* Section, is to be congratulated for having engineered a movement which brought together at one meeting three very capable gentlemen on a very timely and popular subject, "Automatic Welding".

The automatic welding field was well covered, including submerged-arc welding using A. C. Scott connected and Delta systems, CO_2 welding, inert-gas metal-arc welding and inert-gas tungsten-arc welding.

W. C. Levering, electric welding sales representative of the Linde Co., covered the submerged-arc welding using A. C. Scott connected and closed Delta systems.

E. R. Gamberg spoke on the carbon-dioxide welding which is becoming very popular. Mr. Gamberg is supervisor of Arc Welding Equipment Laboratory of the Westinghouse Corp.

Inert-gas metal-arc and inert-gas tungsten-arc welding were discussed by H. S. Davis, process engineer, Equipment and Marketing, Air Reduction Sales Co. He covered inert-gas welding of parts ranging from no bigger than a pencil eraser to the largest tube mill in the world.

The above meeting and dinner were held on Friday, October 3rd in the Engineers Club.

PANEL DISCUSSION HELD IN PHILADELPHIA

Automatic welding was discussed at the Panel Meeting held by the Philadelphia Section. Panel members are (*left to right*) W. C. Levering, E. R. Gamberg and H. S. Davis

Panel Moderator Dave Buerkel and Panel Discussion Chairman A. C. Young are shown in deep conversation at the meeting held in Philadelphia on October 5th

John T. Thomas of Grumman Aircraft, Bethpage, L. I., N. Y., gave a very informative talk on welding processes that are employed in welding light-gage aluminum and high-temperature alloys. Mr. Thomas' talk covered joint design, cleaning procedures prior to welding, reasons for selecting a specific process, fixturing and, in some instances, subsequent forming of the welded part. His talk was frequently interrupted by questions from the audience. These questions enabled Mr. Thomas to elaborate on the very clear and interesting slides which he used to supplement his talk.

Rhode Island

WELDING OF ALLOYS

Providence, R. I.—The first meeting of the *Providence* Section for the new season was held on October 15th at Johnson's Hummocks. After dinner, a short business meeting was called to order by Everett Brunnckow, 1st vice chairman. Avery Seaman was called upon to inform the members of the coming New England Regional Conference. Mr. Seaman gave a complete description of the program beginning with the educational sessions in the morning through the welding demonstrations and technical sessions in the afternoon. The day was climaxed by a banquet in the evening.

SPEAKS ON BRAZING

High-temperature brazing for nuclear reactors was the subject of P. Patriarca's talk before the Northeast Tennessee Section on September 16th

Tennessee

BRAZING

Knoxville, Tenn.—On Tuesday night, September 16th, Peter Patriarca, head of the Welding and Brazing Laboratory of the Oak Ridge National Laboratory Metallurgy Division, presented a talk before the *Northeast Tennessee* Section on "High-Temperature Brazing for Nuclear Reactors." The present applications of brazing, together with potential uses, were described with regard to nuclear reactors in general as well as for several basic reactor systems.

The importance of proper brazing atmosphere purification to obtain satisfactory flow was stressed, and the significance of neutron-absorption cross section of brazing alloys was discussed. Methods of determining the corrosion resistance of brazing were described, and typical examples of acceptable and unacceptable alloys in certain environments were shown. The various media in which testing have been conducted include air, pressurized water, sodium, and fused salts.

High-temperature brazing serves as a particularly useful fabrication procedure in the fabrication of fuel elements. It has been used successfully in construction of the Army Power Package Reactor fuel elements and might be proposed for certain applications in some gas-cooled reactor fuel element designs.

Heat-exchanger fabrication is another field of reactor component construction which is ideally suited for brazing. Tube-to-tube sheet joints may be back-brazed to minimize the possibility of leaks due to thermal-stress cracks, to weld defects, and to stress-corrosion cracking. The procedures for brazing small-scale, as well as larger units, were described.

Many other reactor test components have been fabricated by brazing. These include liquid-metal pump impellers, high-temperature cermet valves and finned-tube heat dumps. The construction of the finned-tube heat dumps was described in detail, including the manufacture of sintered brazing-alloy rings and the special ejector mechanism for applying the rings to the units. The brazing-alloy liquation obtained with slow heating rates was discussed as a potential problem unless adequate preventive measures are used.

Texas

WELDING PROCESSES

Houston, Tex.—The September 24th meeting of the *Houston* Section was held in the new Houston Engineering and Scientific Society Building.

Technical speaker was Orville T. Barnett, assistant manager, Metals Research, Armour Research Foundation of Illinois Institute of Technology, Chicago. In his talk on "Selection of Proper Welding Process" Mr. Barnett covered arc welding, gas welding and brazing for steel, cast iron, stainless steel, aluminum, copper and nickel-base alloys. He explained why certain processes are used for certain applications and included, in addition to these processes, resistance-welding applications.

Before the meeting, a film "Highlights of the Southwest Conference—1957" was shown through the courtesy of the Humble Oil & Refining Co. of Houston.

SAFE PRACTICES

Beaumont, Tex.—The *Sabine* Division of the Houston Section met on

HOUSTON SECTION HEARS TALK ON THE SELECTION OF WELDING PROCESSES

The factors involved in the selection of welding processes were described by O. T. Barnett at the September 24th meeting of Houston Section. Left to right are: Section Chairman H. F. Crick, Mr. Barnett and M. C. Avis

More than 110 members and guests were on hand to hear Mr. Barnett. Above, Mr. Crick is shown addressing those present

HELTON SPEAKS ON LOW-HYDROGEN ELECTRODES

Seth Jenkins, chairman, introducing D. C. Helton, guest speaker at the October 14th meeting of North Texas Section

Eighty-two members and guests were on hand to hear Mr. Helton's talk on "Evolution of High-Tensile Weld Metal with Low-Hydrogen Electrodes"

September 25th for dinner and meeting at the Flying Chef Cafe, Jefferson County Airport. The subject of the meeting was "Safe Practices for Electric and Gas Welding and Cutting Operations." Three speakers were scheduled as follows: Nelson Derrick, safety engineer, Construction Department, DuPont Co., Orange, Tex.; G. H. Bradley, safety engineer, Bethlehem Steel Co., Beaumont, Tex.; and R. C. Blanchard, safety engineer, Gulf Oil Corp., Port Arthur, Tex.

Each of these speakers covered certain phases of safety in welding.

Mr. Derrick's talk covered:

(1) Hazards of fire and prevention of same by wetting down the working area, use of blankets, sheeting, etc.

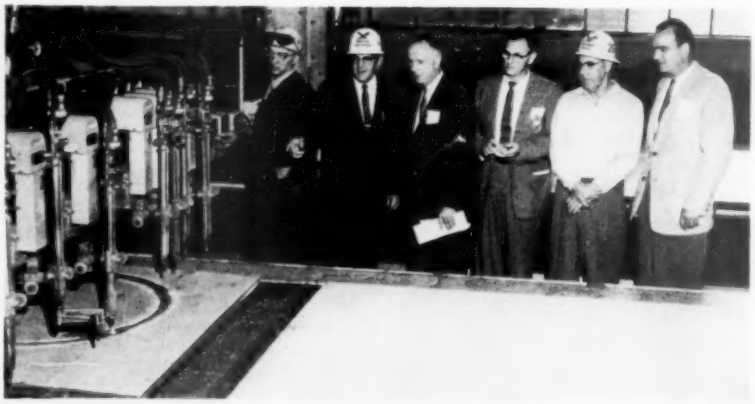
(2) Precautions in the use of welding and cutting in areas which contain unknown atmospheres.

(3) Screens and shielding to protect operators and assistants.
(4) Safe clothing for operators.
(5) Safe use of compressed gases.

Mr. Bradley's talk covered:

(1) Low-voltage shocks.
(2) Reasons for low-voltage shocks.
(3) Connection between length of time of shock compared to severity of shock.
(4) Results of shocks in contact

SECTION VISITS PUGET SOUND NAVAL SHIPYARD



Group of visitors from the Puget Sound Section being shown an oxygen-cutting operation during their visit to the Puget Sound Naval Shipyard on August 14th

More than 100 members and guests attended the summer meeting and field trip

with different parts of the body.

Mr. Blanchard's talk covered:

(1) Case histories of accidents that had occurred during last year with the amount of time lost.
(2) Radiation protection by survey meters, use of safe practices, use of dosemeters
(3) Cutting and welding on vessels and other containers.
(4) Toxic gases and ventilation for (3).
(5) Performance of test for CO, H, H_2S before welding.
(6) Good air venting of tanks and vessels and dangers of welding and burning on vessels that had been in lead use.

LOW-HYDROGEN ELECTRODES

Fort Worth, Tex.—On Tuesday, October 14th, 82 members and guests of the *North Texas* Section met at the Western Hills Inn for the regular monthly meeting. Dinner was preceded by a social half-hour.

D. C. Helton, research engineer with the Electrode Division of the Harnischfeger Corp., was the guest speaker for the evening. His talk on "The Evolution of High-Tensile Weld Metal with Low-Hydrogen Electrodes" was effectively illustrated by color slides. Mr. Helton stressed the progress which has been made since World War II in reducing the strategic alloy content of these electrodes and the improved heat-treat response of deposited weld metal.

POWER SOURCE FOR WELDING IS TOPIC OF TALK

At the September 19th meeting of Fox Valley Section, the members and guests present heard W. L. Sykes present a paper on "Power for Welding." Left to right above are: Max Kern, Mr. Sykes and John Weigand

Washington

SUMMER TOUR

Bremerton, Wash.—This year, for the first time, the *Puget Sound* Section held a summer meeting and it was very successful. One hundred and six members and guests toured the welding and fabrication shops of the Puget Sound Naval Shipyard. They were also very fortunate in having a tour of the U.S.S. *Coral Sea*, an aircraft carrier that is being converted for jet aircraft service, thereby noting the various interesting applications of welding that are being used to convert this vessel. They were also given a tour of the U.S.S. *Missouri* where the World War II surrender was signed. All in all, through the very wonderful kindness and cooperation of the members of the Puget Sound Naval Shipyard, this was one of the most interesting and informative meetings and field trips held by this Section.

Wisconsin

POWER FOR WELDING

Appleton, Wis.—The first meeting of the *Fox Valley* Section for the 1958–59 season was a marked success. The meeting was held at the Appleton Elks Club on Friday evening, September 19th.

MILWAUKEE SECTION ADDRESSED BY KIERNAN

Mayor Frank P. Zeidler of Milwaukee delivering his coffee talk at the October 17th meeting of Milwaukee Section. Interested spectators (*left to right*) are Section Chairman, R. Keller, guest speaker J. F. Kiernan and W. Dyble

Mr. Kiernan spoke on the "Recent Developments in Natural Gas Cutting." Here he is receiving a standing vote of thanks by Chairman Keller

A Kimberly Clark Corp. prepared film on the Fabrication of Stainless Steel was shown, with commentary by Messrs. Greaves and Eckholm of that company. The film gave excellent coverage of the subject of fabricating stainless-steel pipe, elbows and shapes, including repair and maintenance in the field. The film and comments were interesting and educational.

Speaker of the evening was W. L. Sykes, chief electrical engineer, Miller Electric Mfg. Co., Inc., whose topic was "Power for Welding." The subject was unusual and quite different. Mr. Sykes discussed power from the time it was created; its transmission to the point of usage; the differences in types of power; the changes made in power at the welding machine for various welding operations; and strengths and weaknesses of welding machines. He also pointed out that improvements in welding machines of today are so great as to make a welding machine ten years or more of age obsolete.

The meeting was attended by 68 members and guests. Refreshments were served immediately following the meeting.

GAS CUTTING

Milwaukee, Wis.—The *Milwaukee* Section held its second meeting of the current season on October 17th at the Ambassador Hotel.

Mayor Frank P. Zeidler of Milwaukee gave an interesting coffee talk on building and construction codes for the modern era, and specifically mentioned the potential of welding in the future.

J. F. Kiernan, development engineer of Airco, Union, N. J., presented a technical talk on "Recent Developments in Natural Gas Cutting." The talk was well received by the 103 members and their guests, and many pertinent questions on this subject were discussed. Charts, graphs and other technical data were also presented by Mr. Kiernan.

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SURVEY RESULT #5*

* At the request of a leading advertising agency, a survey was directed to a group of Welding Journal readers specified by the agency. Here is one of the many interesting points that came to light. The actual surveys are available for inspection at any time.

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A—Sustaining Member B—Member C—Associate Member

D—Student Member E—Honorary Member F—Life Member

Total National Membership

Sustaining Members	193
Members	5,991
Associate Members	5,742
Student Members	188
Honorary Members	9
Life Members	16
Total	**12,139**

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Farrell, F. L. (C)

BATON ROUGE
Delaune, Ray (B)
Landry, Earl (B)
Paxton, C. L. (B)
Ray, J. (B)
Wheat, W. James (B)

BIRMINGHAM
Beaners, C. S. (C)
Crockett, J. M. (C)
Gayle, Walter G. (B)
McCaffrey, Harold (B)

BOSTON
Fisher, A. F. (C)
White, Sheldon Seymour (C)
Wicks, Gerard R. (C)

CANADA
Hilliard, Jan (B)

CAROLINA
Notley, C. G. (A)
Powell, Russell V. (B)

CHICAGO
Chapman, William R. (B)
Dejka, Robert Leo (B)
Koops, Hans O. (B)
Samans, Carl H. (B)
Severs, John R. (C)
Stephens, Vollie V. (C)

CLEVELAND
Horrigan, V. J. (C)
Raymond, Marshall D., Jr. (C)

COLORADO
Mathes, E. L. (B)

DETROIT
Batherson, Dan (C)
Burthwick, Ross M. (B)
Collier, Wm. Curtis, Sr. (B)
Johnston, Wilber R. (B)
Kobiela, John (C)
Schleicher, Louis C. (C)
Shorek, Leonard J. (C)
Smith, Lawrence E. (C)
Ward, Robert C. (C)
Willard, W. E. (C)

HOUSTON
Carroll, James B. (C)
Mason, James W. (B)
Minnigerode, Charles E., Jr. (C)
Morgan, Preston D., Jr. (C)
Troegel, E. F. (C)

INDIANA
Gillespie, Joseph (C)
Hodges, Cleo C. (B)
Smucker, Milt (C)

IOWA
Tilton, Herbron (B)

IOWA-ILLINOIS
Ward, Robert V. (C)

KANSAS CITY
Braley, Ernest (C)

LONG ISLAND
Allgood, Lee (C)
Blitz, Arthur (C)
Evans, Arthur (C)
Gaucher, Warren A. (C)
Giambra, Frank (C)
Gradilone, Frank (C)
Graziose, Gene (C)
McCallum, Richard (C)
Nickerson, George (C)
Wieland, Frank A. (C)
Zwerling, Seymour J. (B)

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Cruz, Eduardo E. (D)
Duff, James G., Jr. (B)
Gill, Balleen (D)
Schaeffer, Don (D)
Temme, Edwin R. (B)

LOUISVILLE
Hill, Arthur S. (C)
Karthman, Joseph D. (C)
Van Meter, Wilson M. (C)
Wells, Vincent J. (B)
Wood, Walter W. (C)
Wyatt, Donald D. (B)

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Duchon, Gerald A. (C)

MAHONING VALLEY
Sams, Raymond D. (D)
Sutter, Robert F. (C)

MILWAUKEE
Lundgreen, Owen T. (C)
Stark, W. Hans (B)

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Irwin, Isaac H. (B)

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Buley, Vincent F. (C)
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Hooper, Harry (C)
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Peterson, Ross S. (C)
Quinn, Edward J. (B)
Smith, Carlton N. (C)

NEW ORLEANS
Hebert, Euclid M. (C)
Lehman, Richard Karl (C)

NEW YORK
Brown, Paul Philip (B)
Gallacher, Thomas (B)

NORTH TEXAS
Anderson, E. A. (C)
Banister, Oscar L. (C)
Butler, Howard E. (B)
Hutchison, Donald L. (C)
Nye, Richard E. (C)

NORTHEAST TENNESSEE
De Walt, Dave L. (B)

NORTHERN NEW YORK
Kennedy, John M. (B)
Stockholm, Robert Q. (C)
Swart, Homer D. (C)

NORTHWEST
Enger, V. W. (C)
Frederickson, Kennard (C)

OKLAHOMA CITY
Cain, Archie (C)
Holmes, Carl A. (C)

OLEAN-BRADFORD
Ransom, Dean Adelbert (C)

PASCAGOULA
Akins, Gilbert (C)

PEORIA
Webb, Tipton V. (C)

PHILADELPHIA
Dyczynski, Edward (B)
Fisk, H. Frank (B)
Hoenig, Joseph G. (B)
Trueman, Daniel G. (B)

PITTSBURGH
Gross, A. R. (C)
Jud, Karl R. (C)
Mosshart, D. J., Jr. (B)
Murphy, A. J. (C)
Schuster, R. H. (C)
Shonborn, Paul J. (C)
Smith, William C. (C)

PROVIDENCE
Weber, William G. (B)

PUGET SOUND
Lovell, Don T. (C)
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Monahan, Joseph F. (B)

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Kelly, John T., Jr. (B)

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Lambert, James William (B)

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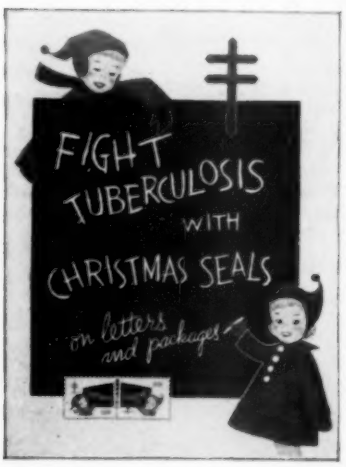
NORTH CENTRAL OHIO
Douglas, W. G. (C to B)

PHILADELPHIA
Joseph, E. R. (B to A)

SAGINAW VALLEY
Engle, Thomas (C to B)
Hunt, Wayne L. (C to B)



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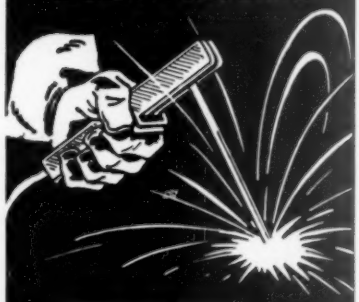

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NEWS of The Industry

Fabrication Completed on Welded Aluminum Highway Bridge

Climaxing an extensive research and development program jointly sponsored by the State of Iowa and the nation's three largest aluminum producers, the first aluminum girder type highway bridge in the world was dedicated recently in Des Moines, Ia.

The 222-ft long welded structure was officially opened to traffic with the cutting of a ribbon made appropriately of aluminum foil.

In attendance were state and city dignitaries, members of the Iowa State Highway Commission and Des Moines Chamber of Commerce, visiting highway administrators and engineers from throughout the nation, and representatives of the three sponsoring aluminum companies, Aluminum Company of America, Kaiser Aluminum & Chemical Corp. and Reynolds Metals Co.

A two-lane, 4-span continuous girder structure with a reinforced concrete deck, the bridge is located on Clive Rd. and crosses Interstate 35 and 80, a four-lane express highway. It is 36 ft wide with a 30-ft roadway.

The aluminum bridge is a developmental project to demonstrate structural and fabrication advantages of aluminum and to stimulate broader use of the metal in the nation's huge highway construction program.

It was designed by Ned L. Ashton (AWS), Iowa City consulting engineer, under the direction of the Iowa Highway Research Board and the Iowa State Highway Commission. The aluminum fabrication was performed by Pullman-Standard Car Manufacturing Co., Chicago, and general contractors were Jensen Construction Co. and United Contractors of Des Moines.

The aluminum structural members were shipped in four giant subassemblies by rail from Chicago to a point near the site and then completed the journey by truck-trailer. The subassemblies, each consisting of an exterior and interior girder with connecting diaphragms, were approximately 12 ft wide and ranged from approximately 95 to 126 ft in length.

The big sections were then quickly and easily elevated to concrete piers by crane and bolted in place, thus demonstrating the simplicity of field erection made possible by the prefabrication of the relatively lightweight members. Casting of the concrete deck and installation of railings completed the project.

A further important advantage expected to be demonstrated by the bridge is elimination of maintenance costs for painting. A similar bridge of conventional materials requires re-painting from time to time to protect it from corrosion.

Four continuous longitudinal girders are used under the roadway spaced $9\frac{1}{2}$ ft apart. The girder and diaphragm system is primarily of welded plate construction, taking full advantage of high strength weldable aluminum alloys. The plate ranges in thickness from $\frac{1}{2}$ to $1\frac{3}{4}$ in. A typical main girder has a web $\frac{1}{2}$ by 36 in., a lower flange $1\frac{1}{4}$ by 18 in. and an upper flange $\frac{3}{4}$ by 12 in. A typical diaphragm has a $\frac{1}{2}$- by 23-in. web and 1- by 10-in. flanges.

The concrete deck is tied rigidly to the aluminum girders with aluminum shear connectors to achieve composite action. Aluminum offers certain structural advantages when used for members designed for composite action with the concrete road slab, permitting a reduction in aluminum weight.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

40th Annual Meeting and Seventh Welding Show:
April 6–10, 1959. Sherman Hotel, Chicago, Ill.

1959 National Fall Meeting:
September 28–October 1. Sheraton Cadillac Hotel, Detroit, Mich.

41st Annual Meeting and Eighth Welding Show:
April 25–29, 1960. Biltmore Hotel, Los Angeles, Calif.

NEMA

January 26–29, 1959. Plant Maintenance and Engineering Show. Cleveland Public Auditorium.

March 12, 1959. Arc Welding Section Quarterly Meeting, Pittsburgh.

Midwest Welding Conference

January 28–29, 1959. Illinois Institute of Technology, Chicago. Sponsored by Armour Research Foundation and AWS Chicago Section.

IAA

March 9–11, 1959. Annual Meeting. Roosevelt Hotel, New Orleans, La.

Western Metals Exposition

March 16–20, 1959. Eleventh Western Metal Exposition and Congress, ASM and other technical groups, Pan-Pacific Auditorium and Ambassador Hotel. Los Angeles, Calif.

Methods for Brazing Copper Wires

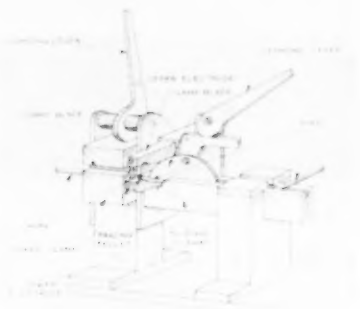
A new system for electric brazing solid and stranded wire, particularly copper wires, has been developed by Maurice G. Steele, development engineer of Rome Cable Corp., Rome, N. Y. A U. S. patent has been awarded to Mr. Steele and assigned to Rome Cable.

Mr. Steele's system centers around the use of two opposed mechanical metal clamps, one on each side of a standard carbon-block brazer using opposing electrodes. One, a fixed clamp, is separated from the electrode by a small air gap of approximately $^1/_{64}$ in. The other is a spring-action sliding clamp designed to move horizontally in with the electrode groove and towards the other clamp.

To braze, one wire is inserted in the fixed clamp, so the wire end extends nearly halfway through the groove in the adjacent lower electrode. A small pellet of brazing metal is placed in the groove adjacent to the wire end.

The other wire is placed in the sliding clamp so it lies in the lower electrode with the end touching the opposite end of the brazing pellet. A stop device holds the clamp about $^1/_{32}$ in. from the electrode.

Next, the upper electrode is lowered to enclose both wire ends and the brazing pellet. Pressure on the sliding clamp is released so it presses one wire end against the pellet and in turn, the pellet against the other wire end.



Current is applied and the spring action of the sliding clamp causes one wire end to move through the electrode groove towards the other wire end as the pellet is melted. A strong brazed joint is formed where the wire ends meet.

Cornell Students Sweep Lincoln Awards

Five engineering undergraduates at Cornell University received all of the top awards this year in the annual mechanical and structural welded design competition sponsored by The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio.

Top award of $1250 went to Richard Jarvis of Baltimore for his design of a triangular shaped foot bridge. John Jenner and E. R. McLean of LeRoy, N.Y., and Philadelphia, respectively, shared the $1000 Second Award for the mechanical design of an automatic welding machine. Gordon Kraus and Robert Spicher designed a display arboretum which received the $500 Third Award. Honoring these awards, Cornell received $1750 in scholarship funds to be administered by the Mechanical and Civil Engineering Departments.

The 1958–59 Rules booklet for the current competition is now available from The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio. Undergraduates in all branches of engineering are eligible to participate.

Kraft Paper Used in Inert-Gas Welding

An ingenious use of 50-lb kraft paper has been developed to make possible field application of inert-gas welding methods.

Use of inert-gas welding in the field of pipe has been limited by the difficulty in retaining the gas in the weld area and then disposing of the retaining device.

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By using a circular piece of kraft paper attached with masking tape as a baffle 6 in. from the ends of the pipe to be joined, Robert T. Pursell [AWS], metallurgical engineer with Stone & Webster Engineering Corp., solved the problem.

The paper is able to withstand the pressure of 3 or 4 oz per in. exerted by the inert gas and the welding heat of up to 600° F. But at the end of the welding process, during the annealing or stress-relieving phase, both the paper and the masking tape disintegrate, leaving the pipe clean.

NWSA Studies Cost Control

A succession of boom years following World War II has nurtured a generation of executives who are often inept in cost control procedures, F. L. Fletcher, of Alderson Associates, Inc., told members of the National Welding Supply Association at a recent meeting of the NWSA's Eastern Zone at the Sheraton Hotel, Philadelphia. Mr. Fletcher said that because the philosophy of "spend and spend, grow and grow" has succeeded for business in recent years, management has tended to lose sight of the importance of such fundamentals as cash and cost controls. This has been detrimental to their companies and the general business climate, he declared.

The recent slowdown in business activity may have been a disguised blessing, Mr. Fletcher suggested, particularly for the small or medium-sized enterprises, through forcing them to remedy their neglect of these older and less glamorous fundamentals of running a business. It is always dangerous, he warned, to forget the real and continuing risk of business failure.

To ensure the solvency and profitable conduct of any business, Mr. Fletcher outlined a basic four-part program for checking a firm's operations in the areas of fiscal and cost control, marketing appraisal and efficiency evaluation.

AIRCO AND MASTIC TILE FORM CORPORATION

The first board of directors meeting of the newly formed Cumberland Chemical Corp. discusses plans for their $10 million plant in Calvert City, Ky., to produce vinyl chloride monomer and polymer, and a new type of plasticizer. Seated (*left to right*) are R. B. Schneider; Seymour Milstein, president of Mastic Tile Corp.; President John A. Hill of Air Reduction; J. D. Gunther, president of Air Reduction Chemical; and C. J. McFarlin, Airco vice president

Successful Welding Clinic

The Action Welding Co., Inc. of Baton Rouge, La., held its first welding show on September 19th and 20th.

The companies taking part in this event were: Welsh Mfg. Co., Smith Equipment Co., Metal and Thermit Corp., Fibre Metal Co., Alloy Rods, Handy & Harman, Metal Removal Co., Emerson Electric Co., Vickers Electric Corp., and an AMERICAN WELDING SOCIETY booth for the purpose of supplying welding advice and promoting AWS memberships. Some of the steel welded products displayed were fabricated by the Delta Tank Co., Inc., Yaun Mfg. Co. and Cal-Metal Pipe Corp., from the Baton Rouge area.

The show was opened by the Honorable Mayor Jack Christian cutting a chain at the entrance with an oxyacetylene torch, with Opie Shelton, president of the Chamber of Commerce of Baton Rouge, Senator J. D. Deblieux of Louisiana, Sheriff Brien Clemmons, Ray Burgess of the Department of Public Works and J. Bowling, director of the Baton Rouge Trade School with 25 of his welding students looking on.

The Action Welding Co., Inc. executives Eugene Funk, president, Guy Funk, vice-president, Charles F. Funk, general manager, John E. Funk, manager, and O. J. Templet, sales manager, were on hand to welcome the visitors and introduce them to the booth attendants.

Mayor Jack Christian of Baton Rouge severs the chain with an oxygen-cutting torch, thereby officially opening the welding show. Admiring the Mayor's expert efficiency are (*left to right*) O. J. Templet, sales manager at Action Welding Co.; J. Bowling, director of the Baton Rouge Trade School; and F. Murphy, Fibre-Metal Products Co.

Television Station WAFB was on hand to record the welding show.

Young and old were permitted to try their hand in welding or in operating the equipment displayed at each booth. Great interest was shown by all, especially the Trade School students, ranging from the age of 16 to 26 yrs.

317 persons registered for the attendance prizes, ranging from an outboard motor and a complete oxyacetylene cutting-welding outfit to smaller prizes.

The Action Welding Co., Inc. is a supporting member of the AMERICAN WELDING SOCIETY. They support their own private school for employees, and classes are held each week training them in metallurgy and joining of metals by welding. This program is directed by J. O. York, chief welding engineer for Delta Tank Co., Inc., and Director-at-Large of the AMERICAN WELDING SOCIETY.

NCG Acquires Mexican Interests

Acquisition of substantial interest in five industrial gas firms in Mexico was announced recently by President Fred C. Heppel of NCG International, C.A., a subsidiary of Chemetron Corp., Chicago.

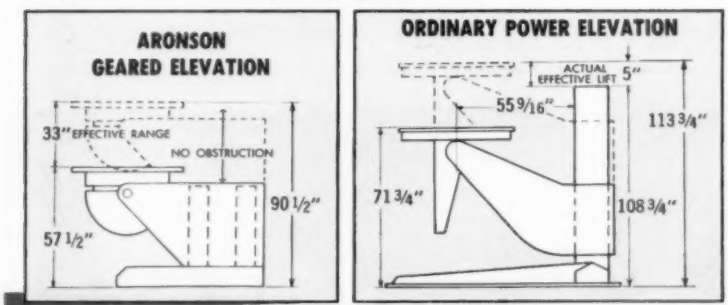
Construction of Mexico's first liquid argon plant has been started by one of the five, Argon de Monterrey, S.A., with production scheduled for early 1959. The installation at Monterrey, a steel industry center, will also produce liquid oxygen and nitrogen for distribution in a wide area.

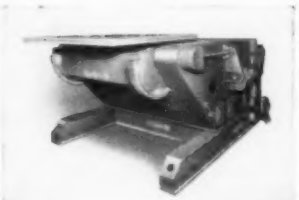
Other producing companies included in the transaction are Cia. Productora de Oxigeno, S.A., Monterrey, which manufactures oxygen and acetylene; Electrodos Monterrey, S.A., manufacturing oxygen and acetylene gases in Mexico City and welding electrodes and gas welding wire in Monterey; and Oxigeno de Chihuahua, S.A., Chihuahua, producing oxygen and acetylene.

Products of these companies are marketed by the fifth of Chemetron's new Mexican affiliates, Gases y Electrodos, S.A., a sales and distribution service company maintaining branches in Torreon, Guadalajara and Culiacan and agencies in principal cities throughout Mexico.

Aronson GEARED ELEVATION Versus Ordinary Power Elevation

The best working position is as near the floor as possible. The only reason to elevate the work on the positioner is to give floor clearance for extra large work pieces.





In the ordinary positioner the workpiece can be no bigger than 9'-3" in diameter if it is to clear the single post sticking up the back.

This means that the single-post design requires large work to be loaded on the table in the flat position when the table is at least 108 3/4" (over NINE FEET high!) above the floor.

At that height, there is only FIVE INCHES additional height range!

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M & T Creates Market Group

Metal & Thermit Corp. has recently widened the scope of its development activities. To be known as M. & T.'s development department, reporting direct to H. E. Martin, the company's president, this department is now not only responsible for market development and market research, but also for product development, a new technical activity being conducted at the M. & T. research center in Rahway, N. J. H. E. Hirschland, former manager of market development, has been named director, and C. H. Carpenter, formerly technical advisor to the president, is manager.

While development of new chemicals and metals will be stressed, the work of the department will encompass all of M. & T.'s present product lines, including welding supplies and equipment, electroplating products, organic coatings and products for the ceramic industry.

Welding Inspectors Pass Examinations

The Canadian Welding Bureau has recently announced the results of its examinations for welding inspectors, which took place in 20 centers across the country on the 21st of June.

During the previous 8 months, 163 students participated in the Bureau's home study course on Weld Quality Control and Inspection but only 70 were sufficiently advanced to write. Of these, 50 were entirely successful and will receive their diplomas, while 7 will be permitted to write supplementary examinations in June 1959. Thirteen failed outright.

For the assurance of those employing inspection personnel, and also for responsible engineers and others acting on behalf of owners and buyers, all students who successfully meet the Bureau's requirements are issued a diploma—one 8 x 12 in. for framing and hanging and another, a duplicate, reduced to wallet size and plastically sealed.

Inspectors so qualified are expected to carry such certificates to assure any questioning authorities as to their competency.

Students who are currently taking the course and making satisfactory progress may refer employers or other authorities to the Bureau as to their state of competency.

Airco Expands Facilities at Lorain

Air Reduction Sales Co., a division of Air Reduction Co., Inc., has announced the completion of expansion of its gaseous and liquid oxygen producing facilities at Lorain, Ohio.

The expansion, which was started in

July of 1957 and required a year to complete, boosts daily production capacity of the Ohio plant from 40 to about 100 tons per day. It was made necessary by the large increase in oxygen consumption by local industry for open hearth and Bessemer furnaces, heat treating, welding, gas cutting and various other industrial processes.

Linde Breaks Ground in California

Linde Co., division of Union Carbide Corp., held ground-breaking ceremonies for its multi-million dollar liquid oxygen and nitrogen plant at Pittsburg, Calif., on September 18th.

The plant, covering a 32-acre tract, will be the biggest in the west and among the largest of its kind in the nation.

It will produce 300 tons of liquid oxygen and nitrogen daily after completion in early 1960 and will supply a nine-state area of the west.

Gilbert Meyer, Linde San Francisco district manager, told the gathering that the Pittsburg site was selected because of its nearness to missile testing facilities and the growing steel and chemical industries of the west. He added:

"This area presents the best prospect for our own growth and for the growth of the entire industrial complex which we see developing around us. Our future is tied to the growth of the west."

Illinois Office for Coyne Cylinder

The Coyne Cylinder Co. has opened a new midwestern division office in Glenview, Ill.

This is the fourth regional office of the Coyne Co., and the second to be opened within the past year. Other division offices are located in Memphis, Tenn.; Newark, N. J.; and the home office in San Francisco, Calif.

Manager of the new midwestern division is Raymond A. Harder, formerly manager of Coyne's southern division in Memphis.

California Warehouse for KSM

KSM Products, Inc., Merchantville, N. J., have established a new warehouse and sales office at 656 Folsom St., San Francisco, Calif.

In addition to maintaining a complete stock, the office will supervise and service accounts for the central and Northern California areas as well as activities in Washington and Oregon.

John T. Rayner AWS, former district sales engineer for Philadelphia, has been appointed regional sales manager for the Pacific area. He will be assisted by F. G. Kern AWS, district sales engineer for San Francisco and Northern California.

F. Leonard Hultquist AWS, formerly sales manager of Packo Co., Los Angeles, has been appointed sales engineer at the new KSM office, 1238 S. Atlantic Blvd., Los Angeles.

FUTURE FARMERS WIN TOP HONORS AT ARIZONA WELDING CONTEST

Steve Meehan AWS *(left)*, welding engineer at Phoenix Welding Supply, poses with Robert J. Stewart *(center)* and Fred Lambeth *(right)*, top winners in the Future Farmers of America's local farm welding contest. Young Stewart was awarded a 180-amp welding machine for his first-place construction of a 2-ton unloading grain bin and mixer, while Lambeth copped second prize, an oxyacetylene welding and cutting outfit, complete with tanks, for his combination flat bed and livestock trailer

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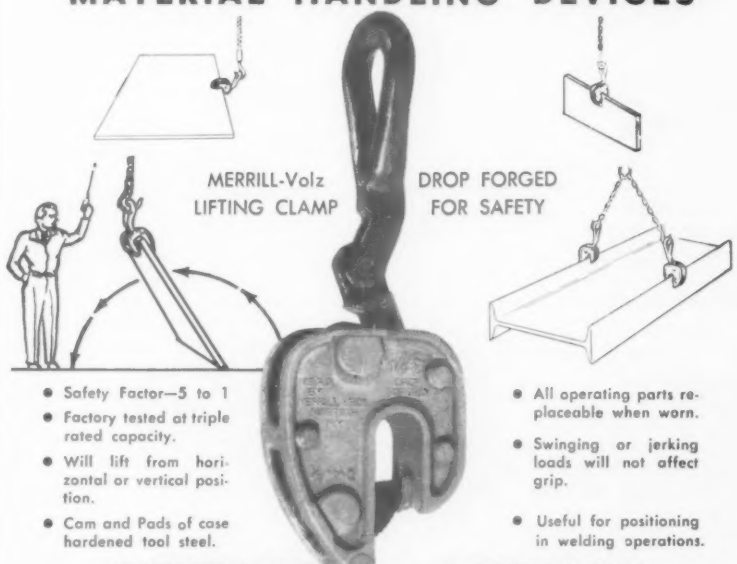

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INTERNATIONAL WELDING NEWS

by Gerard E. Claussen

Yugoslavian Welding Society Issues Magazine

The first issue for 1958 of the new quarterly magazine[1] of the Yugoslavian Welding Society has been received. It is edited by M. Radojkovic in Beograd. There are eight articles, one by Leo Knez, who was a prolific contributor to welding literature before World War II. Several of the articles review the presentations of welding in general; others deal with shipyard welding, repair of tools and residual stresses.

Italians Investigate Hydrogen in Weld Metal

The committee on filler metal of the Italian Institute of Welding[2] has been investigating hydrogen in weld metal deposited by low-hydrogen electrodes. A paper by Botisk describes four accurate methods for determining total hydrogen in coatings. Besides the Gayley-Wooding method, the Jannasch method, involving fusion of the sample with lead oxide, is described. A method in which the sample is extracted in methanol at 113° F and titrated with Karl Fischer reagent also is described. The fourth method involves a microgas burette. The committee discussed results of two types of T crack tests, one of which is suitable for root cracks, the other for surface cracks in stainless-steel welds. The notch toughness of weld metal from mild-steel electrodes of cellulosic rutile, E6020 and low-hydrogen electrodes was discussed. The Italian Navy laboratory showed that an important factor in notch toughness was the distribution of passes and temperature pattern during welding.

Quality Control in Germany

An article by Masing[3] emphasizes the many factors that influence statistical quality control of spot welds besides the electronic timing and phase control equipment. He pleads for a rational attitude of mind on the part of the user in assessing the relative importance of controls, fitup, and other plant factors, and in deciding upon replacement of control components as they wear out.

Welding in the German Chemical Industry

The West German welding magazine for July 1958 contains four articles on welding chemical equipment. Rädeker[4] discusses the welding of steel clad with silver, copper, nickel, Ni-Mo alloys and stainless steels. He emphasizes the avoidance of heat treatment wherever possible. Richter[5] discusses tube welding and cladding in particular, while design rules for solid and laminated vessels operating at high pressures and temperatures are given by Maier.[6] Line drawings of welded jacketed vessels and reactors of steel and copper are discussed in Söhngen's[7] article.

Joint Design and Butt Welds in Belgium

The pulsating tensile fatigue strength of welds joining the flattened ends of steel tubes to gusset plates in tabular structures has been found by Soete and Strebelle[12] to be only 5400 psi, using a lower stress of 1400 psi. The joint design explained the low strength, cracks tending to start at points of incomplete root penetration.

In fatigue tests of welds made in four types of butt joint preparation in steel plate $^3/_8$ to $^3/_4$ in. thick, Daivier[8] found that completely satisfactory results were obtained with deep penetration electrodes and with automatic welding. In these mild-steel welds penetration was complete, and the pulsating tensile fatigue strength was 27,000 psi for unmachined specimens and 34,000 psi for machined specimens, using a lower stress of 1400 psi.

Vibrating Electrode Holder Tested by Czechs

On several occasions in the past claims have been made for improvement in weld quality by using a vibrating holder for covered electrodes. Put to the test in Czechoslovakia,[9] the vibrating holder was found to have no value whatever in eliminating or even decreasing porosity in welds made in difficult positions, such as horizontal butts.

Welding Procedures in Belgian Petroleum Industry

To weld steel containing $2^1/_4$ to 5% Cr and 0.5% Mo in the petroleum industry, deMarneffe[10] uses three procedures. For welds having the same composition as base metal it is necessary to preheat to 570° F and to postheat immediately at 1325° F. For more complicated parts heat treatment is out of the question and Type 310 weld metal is employed. For parts subject to thermal fatigue an Inconel electrode is used with 500° F preheat. Depending upon the application, welds made by this third process may or may not require heat treatment. Ductility is excellent without heat treatment, but the heat-affected zone is somewhat harder than the plate.

A lengthy review of literature on the subject of weld cracking in austenitic steels has been prepared by Sebille.[11]

Welding of Stainless-Steel Castings

The welding of ferritic-austenitic steel castings and wrought products containing, for example, 0.11% C, 25.0% Cr, 5.6% Ni, 0.70% Si, 0.81% Mn is described by Zaks.[13] This steel, called LK3, is specified to have a minimum yield strength of 57,000 psi, and is welded with covered electrodes of the same composition as the base metal or with an electrode containing 0.06–0.12% C, 1.62–2.10% Si, 0.49–1.50% Mn, 18.8–19.8% Cr, 9.00–9.20% Ni, 2.29–2.40% V. There was no trouble with hardening of the heat-affected zone or with grain growth, and preheat was necessary only when heavy beads were deposited or under conditions of high restraint. However, the welds made with the LK3 electrode are subject to intergranular corrosion (120 hr in boiling Strauss solution) and lose their notch toughness if heated for long periods at temperatures of 608° F. Heat treatment at 1200–1560° F for 2 to 3 hr prevents intergranular corrosion.

Soviet Advances

Resistance Welding of Titanium

Spot and seam welded joints in titanium sheet 0.047 and 0.059 in. thick containing 0.08–0.26 Fe, 0.04–0.05 Si, 0.07–0.08 C, 0.012 H_2, 0.13 O_2 and 0.03 N_2, were subjected to static and fatigue tests by Russian authors.[14] Both butt and lap joints were tested. Conditions for the spot and seam welds in the 0.059-in. sheet were: 4-in. electrode radius, 8000 amp for spot, 9000 amp for seam welds, 1100 lb pressure, 0.3 sec spot time, 0.20 and 0.40 sec on-and-off time for seam welding. The spot diameter was 0.24 in. (−0.02, +0.04 in.), which was also the width of the seam welds. The results of static and fatigue tensile tests are given in Table 1. The low- and high-frequency fatigue tests were at 5 to 15 cycles per minute and 2000 to 2800 cycles per minute, respectively. The minimum stress in the fatigue tests

Dr. Gerard E. Claussen is associated with the Development Laboratories, Linde Co., Newark, N. J.

Table 1 Static and Fatigue Strength of Spot- and Seam-Welded Titanium

	Static tensile strength, psi		*Low-frequency fatigue strength for 10,000 cycles, psi*		*High-frequency fatigue strength for 10 million cycles, psi*	
	68° F	*660° F*	*68° F*	*660° F*	*68° F*	*660° F*
Unwelded	86,000	43,000	71,000	28,500	40,000	28,500
Seam weld	86,000	43,000	21,000	14,000	7,100	4,300
Spot weld	68,000	37,000	15,500	13,000	3,000	3,000

was one-tenth of the maximum. Single-row spot-welded joints had the same strength as double row joints in the low-frequency tests but the latter were stronger in the static and high-frequency tests.

Flat Electrodes and Cover Strips

A Russian paper[15] on contact resistance presents measurements of the distribution of pressure under flat electrodes, and of the distribution of current in the sheets between the electrodes. Another Russian paper[16] describes the seam welding of butted sheets of mild steel and stainless steel using a thin cover strip on each side of the joint. The cover strips were 0.012 in. thick for welding sheets $^5/_{32}$ in. thick. There was some indication that the cover strips were not always fused completely into the joint. Static and fatigue test results were satisfactory.

Arc Pressure in Plate Welding

Further work on the pressure exerted by the welding arc on the plate being welded is reported by a Russian author.[17] With an open arc on a steel plate $^5/_8$ in. thick and currents from 450 to 900 amp, the pressure was proportional to the square of the current at 800 amp. For example, the pressure above that due to electromagnetic component, which was 12 g, varied from 3 g for $^3/_{16}$-in. electrodes to 9 g for $^1/_8$-in. electrodes. The pressure was independent of voltage and travel speed. Consistent results could not be obtained with arcs submerged under flux, because evolution of gas in the flux exerted erratic counterpressures.

CO_2 Welding of Rimmed and Killed Steels

A satisfactory electrode for arc welding rimmed and killed mild steel with carbon dioxide contains 0.05–0.12% C, 0.6–1.0% Si, 1.4–2.4% Mn, according to two Russian writers.[18] Weld metal produced with electrodes containing lower Mn and Si had inadequate notch toughness at −40° F. Electrodes containing aluminum (0.42–0.75%) or aluminum and titanium (0.29% Al, 0.15% Ti) tended toward low ductility. The slag produced by the preferred electrode contained lower FeO and SiO_2 and higher MnO compared with electrodes lower in Mn and Si, and therefore was fluid at temperatures below the melting point of the steel. The preferred 0.079-in. diam electrode produced welds at currents up to 500 amp free from porosity in plates up to $3^1/_2$ in. thick, and free from cracking in a rigid fillet test.

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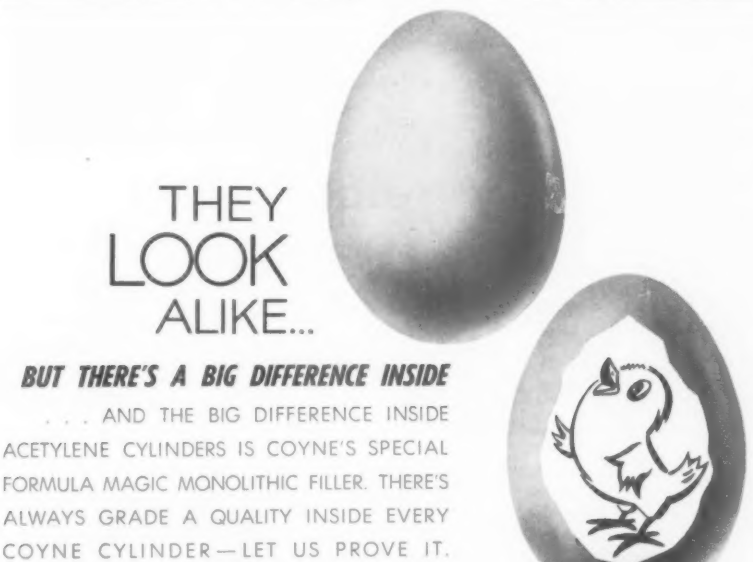
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PERSONNEL

Rosenberg Honored by Franklin Institute

Emanuel Rosenberg of Bogotá, Colombia, was among 17 scientific researchers honored on October 15th in Philadelphia at the occasion of the Franklin Institute's 32nd Annual Medal Day ceremonies. Dr. Rosenberg, the inventor of the cross-field generator, was awarded the Howard N. Potts Medal for "his conception of a fundamentally new principle for deriving electrical current from a rotating machine and for his solution of the many technical problems related to the development of the cross-field generator." The generator, invented in 1904 for train lighting, was adapted by Dr. Rosenberg in 1925 for electric arc welding. Modifications by J. L. Woodbridge, Alexanderson and others created an extensive field of application for control of electric and mechanical machinery. The principle of the generator has been utilized in other fields including that of guided missiles. Dr. Rosenberg has issued many patents and is author of numerous papers and three books, "Electrical Engineering," "The Cross-Field Generator," and "An Engineer's Career."

Born in Vienna, Austria, Nov. 28, 1872, Dr. Rosenberg was graduated from the Vienna Technical University in 1895 as a mechanical and electrical engineer. After serving in several jobs, Dr. Rosenberg in 1917 became director of the Elin works in Austria, where he pioneered in the electric arc-welding field; Dr. Rosenberg left the Elin Co. in 1938.

Jensen Granted Leave from Lehigh

Cyril D. Jensen AWS, professor of civil engineering and chairman of the soil mechanics division of Fritz Engineering Laboratory at Lehigh University, has been granted a leave of absence to accept the post of director of research and testing for the Pennsylvania Department of Highways.

He is a graduate of the University of Minnesota, received his master's degree from Lehigh in 1929, and a civil engineering degree from the University of Minnesota in 1931.

During World War II, he was granted a leave of absence from Lehigh to engage in welding research for the U. S. Naval Engineering Experiment Station at Annapolis, Md. There, from 1942 to 1946, he developed underwater cutting and welding techniques for the Navy and did stress investigations of welded propeller shafts and other weldments. While on this assignment, he obtained a patent for a coated underwater cutting electrode.

Professor Jensen directed a 1954–58 research project on welded interior beam-column connections for the American Institute of Steel Construction.

He has published approximately a dozen research papers, most of them dealing with structural welding; presently, he is chairman of the Lehigh Valley Section of the AMERICAN WELDING SOCIETY.

Professor Jensen is a professional engineer and a member of ASCE, ASEE, ΣΞ and TBII.

Cary to Direct Hobart School

Appointment of Howard B. Cary AWS of Marion, Ohio, as director of the newly established Hobart Brothers Technical School in Troy, Ohio, was recently announced.

The school is a nonprofit school devoted to teaching, research and development in the welding field.

Howard B. Cary

Mr. Cary has resigned his position as assistant general works manager of the Marion Power Shovel Co. He had joined the firm in August 1948, as welding engineer. He became welding superintendent in May 1951, and general superintendent in January 1956. He was appointed assistant general works manager in July 1956. Prior to joining Marion Power Shovel Co., he worked for Battelle Memorial Institute in a research capacity.

Mr. Cary is president of the Marion Chapter of the Ohio Society of Professinal Engineers and is a graduate welding engineer from Ohio State University. He is also a member of ASM, ASME and AIIE. He has served as chairman of both the North Central Ohio and Columbus Sections of the AMERICAN WELDING SOCIETY. At present he is a member of the National AWS Welding Handbook Committee.

Wilson and Kennedy Advanced

Fred T. Wilson, Jr. AWS, assistant manager—sales of Air Reduction's sales office at New Orleans, has been appointed manager at that location, it was announced by H. C. Wallace, regional sales manager.

Fred T. Wilson, Jr.

E. C. Kennedy, salesman, New Orleans, succeeds Mr. Wilson as assistant manager—sales.

With Air Reduction since 1947, Mr. Wilson served in various sales capacities for Airco at Louisville, Ky., and Nashville, Tenn.

Mr. Kennedy has been with Airco for six years and previously was a salesman at Shreveport, La. and Mobile, Ala.

E. C. Kennedy

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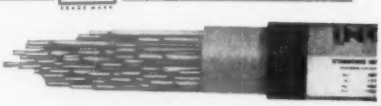

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Ohio State Appoints Green

Prof. Robert S. Green AWS, executive director of the Engineering Experiment Station of Ohio State University since 1954, assumed new duties as associate dean of the College of Engineering on October 1st.

Dean Green, a professor in welding engineering and former chairman of the department, will retain his rank in welding engineering and will continue as executive director of the Experiment Station.

He received his bachelor of science in civil engineering and master of science in engineering in 1936 and 1942, respectively, both from Purdue University.

Before coming to Ohio State in 1947, he served in various capacities with a number of industrial organizations.

Professor Green served as acting chairman of the Department of Welding Engineering from 1947 to 1950 when he was named chairman.

Dean Green will be responsible for the business affairs of the College of Engineering and will coordinate research activities. He will also serve as acting dean in the event of the dean's absence.

Professor Green is also a member of ASCE, ASM, ASTM, ASEE, and the Ohio Society of Professional Engineers.

Merriman Promoted by Airco

R. H. Merriman AWS has been named manager of Air Reduction's Buffalo district, it was announced by A. C. Brown, Jr. AWS, vice president—eastern region. Mr. Merriman has been with the company since 1937 and previously was assistant manager—sales of Airco's metropolitan district at Jersey City, N. J.

Mr. Merriman succeeds H. J. Schlieder AWS, who was with Airco for 38 years, the last 30 of which as manager of the Buffalo district.

F. C. Millspaugh, Jr. AWS, sales assistant at the Jersey City office, succeeds Mr. Merriman as assistant manager—sales there.

R. H. Merriman

Scott Named by Budd Company

Philip W. Scott has been elected a group vice president of the Budd Co. with supervision over the company's Nuclear Systems Division.

Philip W. Scott

Mr. Scott leaves the position of administrative vice-president of the Byron Jackson Division, Borg-Warner Corp., to assume the new Budd post in Philadelphia.

According to the announcement, Mr. Scott will be a member of the Budd Policy Committee, in addition to having direct responsibility over Nuclear Systems.

Scrutton and Williams Promoted

E. R. Walsh, III AWS, vice president in charge of sales for Alloy Rods Co., recently announced the following new appointments to the company's staff.

Harold Scrutton has been assigned the south-central Pennsylvania and Maryland sales territory, as field representa-

Harold Scrutton

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Joseph Williams

tive. Mr. Scrutton will work out of the company's main office in York, Pa.

Joseph Williams AWS, who formerly managed the territory now taken over by Mr. Scrutton, has been promoted to the newly created post of manager of market research. Mr. Williams majored in marketing at the University of Southern California School of Commerce

Gagnebin and Weldon Advanced

The elections of Albert P. Gagnebin as a vice president and Joseph M. Weldon as an assistant vice president of the International Nickel Co., Inc., were announced by Henry S. Wingate, president of the company.

Mr. Gagnebin was elected as assistant vice president in December 1957. He became manager of the Nickel Sales Department in April 1956, after serving as assistant manager beginning in January 1955. His association with International Nickel dates from 1930.

Mr. Weldon has been assistant to the vice president of the International Nickel Co., Inc., since December 1953. He first became associated with the company in 1927 and has held various positions in the sales, executive and other departments.

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Whiting, Indiana

J. E. Smith Promoted

J. E. (Jack) Smith has been elected to the newly created office of executive vice president of Smith Welding Equipment Corp., Minneapolis.

J. E. Smith

Mr. Smith, who has headed the firm's research and development program as a vice president, will now be responsible for day-to-day operations of the company. Mr. Smith joined the company as an employe in 1930. He was elected a vice president in 1943, and became secretary of the firm in 1949.

Mr. Smith was named to organize and head the company's research and development department in 1957, in addition to his responsibility for product engineering. Early this year he assumed an active part in the direction of a sales training program which has since expanded into a nationwide program of distributor development.

Hangen Named by G. E.

The appointment of Donald H. Hangen of Owensboro, Ky., as district sales manager in Cincinnati for General Electric tubes and other components has been announced by Merle F. Johnson, regional distributor sales manager.

Mr. Hangen will cover the marketing areas of Cincinnati, Dayton, Lexington, Ky., and Charlestown, W. Va., succeeding Henry B. Nelson, who recently was named manager of trade relations and distributor development with headquarters in Owensboro, Ky.

A native of Kansas City, Mo., Mr. Hangen received a bachelor of business administration degree from UCLA in 1953 and later obtained a master's degree at Stanford.

OBITUARY

Frank L. Browne

Frank L. Browne, whose membership card indicated that he was the 106th member of the AMERICAN WELDING SOCIETY, died on October 13th at his home in Marblehead, Mass. He was 74.

Throughout his active career in the welding industry Mr. Browne had been associated with Metal & Thermit Corp. and National Electric Welding Machine Co. During the past few years he

represented Precision Welder and Flexopress Corp. in the state of Connecticut. Mr. Browne's friends recall his early professional life as a teacher of mechanical drawing and reveal that his prospective sales sketches reflected that early training.

Mr. Browne is survived by his wife and a daughter.

WELDING ENGINEER

Welding or Metallurgical Engineer interested in welding and brazing research with at least a B.S. degree wanted for investigations into new and challenging areas. Unlimited opportunity will reflect the ability of the applicant.

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Current Welding Literature

For copies of articles, write directly to publications in which they appear. A list of addresses is available on request.

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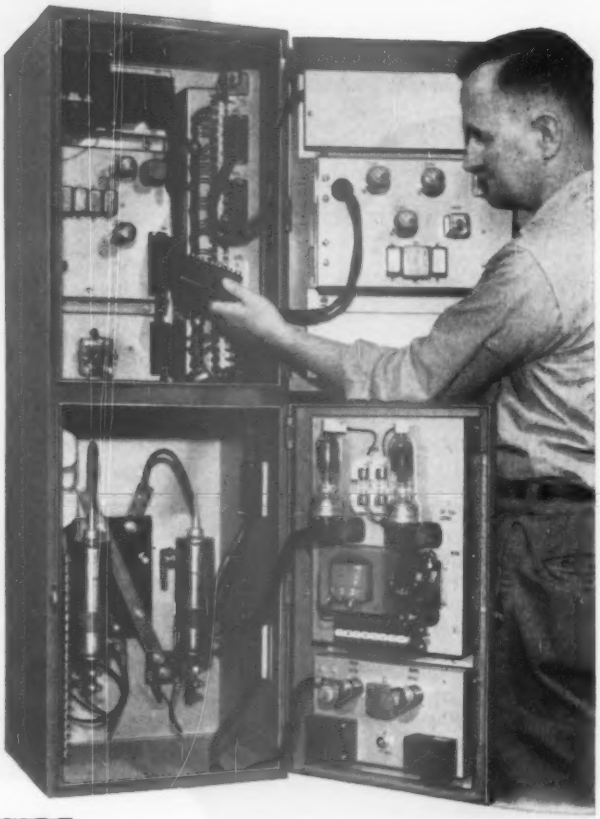

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NEW LITERATURE

AWS Issues Two Specifications on Steel Electrodes

Two new booklets, "Specification for Mild Steel Arc Welding Electrodes" and "Specification for Low Alloy Steel Covered Arc-Welding Electrodes," have been prepared under the combined committees of the AMERICAN WELDING SOCIETY and the American Society for Testing Materials.

The mild-steel specification (AWS A5.1-58, ASTM A233-58) incorporates five changes of note. They are: (1) three new iron-powder electrodes, two of them low-hydrogen types; (2) a new E70XX mild-steel classification containing six electrode types; (3) the inclusion of certain electrodes in the E70XX as well as the E60XX series; (4) a requirement that chemical requirements must be met with certain electrodes to ensure the deposition of mild-steel weld metal; and (5) the addition of two very useful tables in the appendix—Table A showing the mechanical properties to be expected in the as-welded condition and Table B giving a comparison of current ranges.

The low-alloy steel specification (AWS A5.5-58, ASTM A316-58) lists three basic revisions, including: (1) all electrodes must now meet chemical as well as physical requirements if they are to be listed in an AWS-ASTM electrode classification; (2) the addition of a new classification covering electrodes with minimum strengths of deposited metal in stress-relieved condition of 110,000 psi. Designated as the E110XX series, this classification was introduced to satisfy the demand for an electrode between the E100XX and E120XX series; and (3) the addition of new electrodes to Table II, Chemical Requirements, in order to meet the demand for standard electrodes to deposit weld metal having specific properties.

Any changes in mild-steel electrode specifications are important since at least 80% of all welding is done with mild-steel electrodes. Changes in both specifications represent long and careful study of the technical committees assigned to the work.

The specifications are available from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 17, N. Y., at 50¢ each.

Gas Welding and Cutting

Harris Calorific Co., 5501 Cass Ave., Cleveland 2, Ohio, has published a new illustrated 32-page catalog covering all phases of the gas welding and cutting business.

Included in the catalog are welding torches and tips, cutting torches and tips, regulators and welding and cutting accessories.

Also included are specification sheets to meet various types of gas welding and cutting requirements.

For your free copy, circle No. 21 on Reader Information Card.

Welding Supply Catalog

A new 52-page welding supplies and accessories Catalog ADC 848C is available from Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y. Illustrated with over one hundred photographs, this booklet covers Airco's complete line of fluxes and ferrous and nonferrous rods for gas welding; and accessory items including protective clothing, goggles, electrode holders, sparklighters, cable, hose, weld-cleaning tools, cylinder trucks and many other items, for both arc and gas welding.

For your free copy, circle No. 22 on Reader Information Card.

Submerged-Arc Tandem Welding

Increased welding speeds and improved control of bead shape are reportedly the principal advantages of multiple-electrode submerged-arc tandem welding over single-arc operation, according to new Bulletin 5200.2 from The Lincoln Electric Co., Cleveland 17, Ohio. The bulletin describes the tandem-welding process in detail, presenting information on the application opportunities and requirements, and outlining commonly used equipment arrangements.

For your free copy, circle No. 23 on Reader Information Card.

Topics on Surfacing

Volume 3, No. 5 of the September-October 1958 issue of "Colmonoy Alloy News" is available from Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich. Featured subjects of the $8^1/_2$ x 11-in. 4-page folder deal with surfacing of cultivator shovels on a Canadian farm, the surfacing of plate-mill roll guides and the use of one of the Detroit firm's alloys as a production rather than a service life application. The company's new 32-in. vacuum furnace is also described.

For your free copy, circle No. 24 on Reader Information Card.

Welding Used on Statue

The Third Quarter 1958 issue of "Ampco Welding News," published by Ampco Metal, Inc., Milwaukee 46, Wis., features an article explaining certain welding details in the fabrication in Quebec of a 22-ft, 11,000-lb bronze statue of Christ. The 25 sections were joined by inert-gas-shielded arc welding, using $^5/_{32}$-in. E-Cu-Sn-C electrodes and d-c reverse polarity.

Other articles in the 4-page $8^1/_2$ x 11-in. bulletin treat such subjects as the overlaying of composite drawing dies and parts on mooring bits.

For your free copy, circle No. 25 on Reader Information Card.

Aluminum Welding Wires

A 4-page $5^1/_2 \times 8^1/_2$-in. folder entitled "Importance of Filler Wire Surface Quality in High Strength Aluminum Welding" is available from Kaiser Aluminum, 919 N. Michigan Ave., Chicago 11, Ill.

The literature describes Kaiser's recently developed line of King aluminum wires for use in inert-gas-shielded welding in such grades as 1100, 4043, 5052, 5154, 5356 and 5183. Sizes, tempers, packaging and care and storage are also outlined for the spooled and 36-in. wires.

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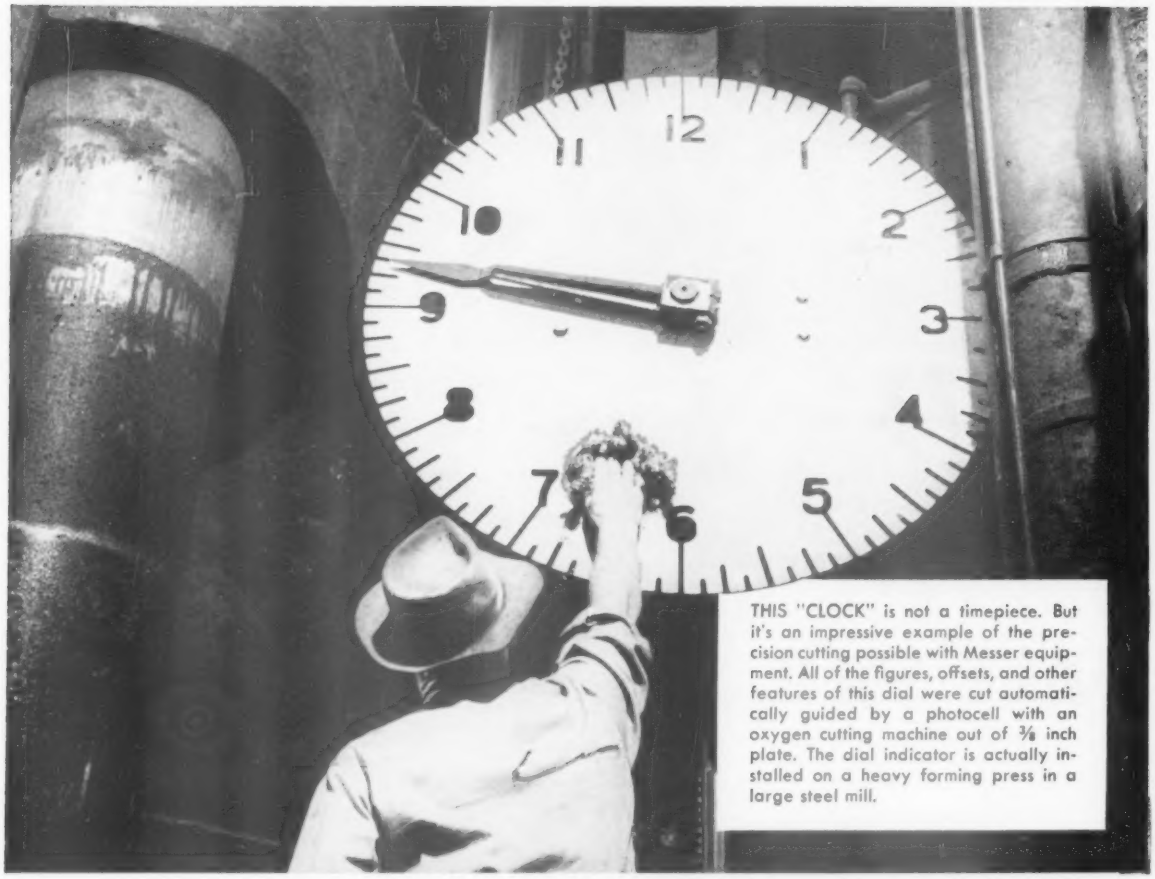

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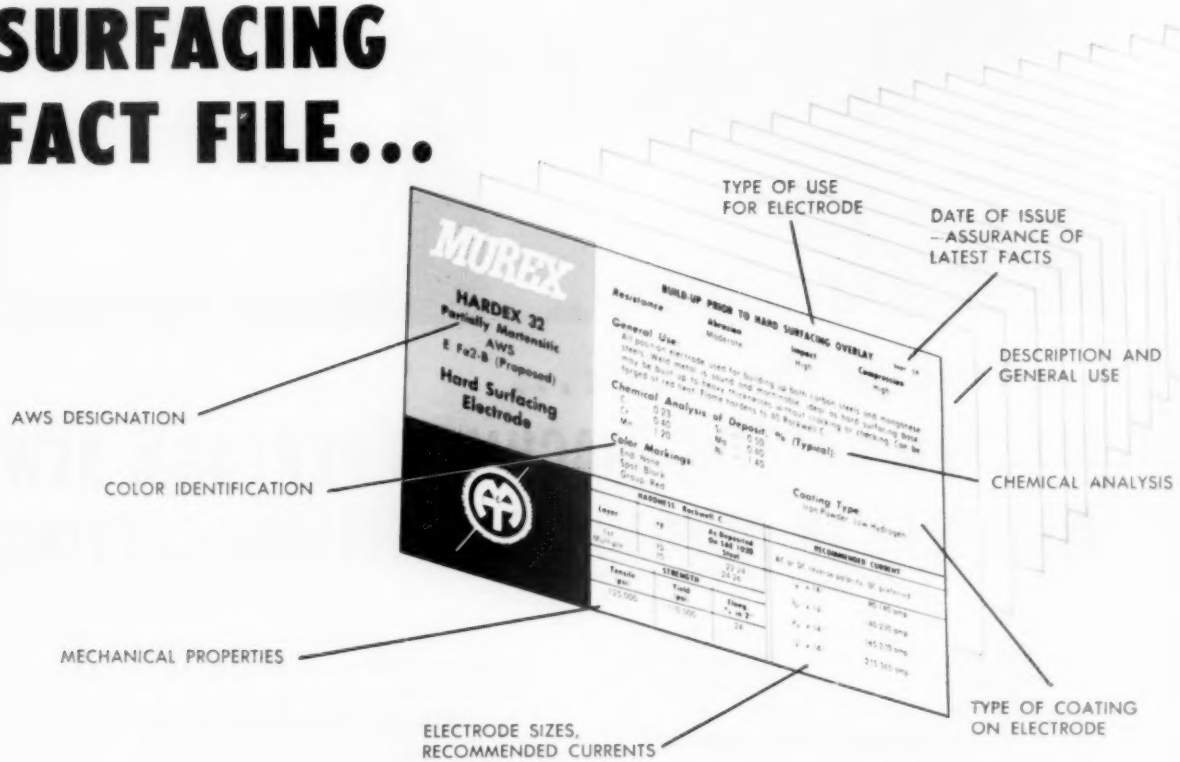

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Metal and Ceramic Sprayed Coatings

A new basic engineering data bulletin on wire and powder sprayed coatings of metals and ceramics has just been published by Metallizing Engineering Co., Inc., 1101 Prospect Ave., Westbury, Long Island, N. Y. Bulletin No. 136A covers their basic characteristics, including hardness, tensile and bond strength of various coatings, plus a wide range of mechanical and electrical-electronic applications which are both illustrated and described. The bulletin also covers various types of spraying equipment including automatic controls used for production line applications of such coatings. A number of tabular data is included, such as spraying speeds, material and gas consumption and square feet covered per hour with various types of metals and ceramics. New materials such as the recently developed tungsten-carbide powders for surfacing applications are also covered.

For your free copy, circle No. 29 on Reader Information Card.

Contact Microradiography

A new 16-page booklet, giving technical facts on contact microradiography for research in the metallurgical and other fields, is available from the Instruments Division, Philips Electronics, Inc., 750 S. Fulton Av., Mount Vernon, N. Y.

The text includes sections which explain the absorption of X-rays and contrast, projection microradiography and contact microradiography, contact microradiography equipment, films and magnification, and applications.

Illustrated with drawings, photographs and micrographs, the new booklet covers the preparation of specimens with respect to fixation, embedding, sectioning, attaching to slides, staining and mounting.

For your free copy, circle No. 30 on Reader Information Card.

Production Welding of Refrigeration Cabinets

An enlarged 8½ x 16-in. issue, No. 583, of "Weld-It," a publication of Taylor-Winfield Corp., Warren, Ohio, describes in color an automated setup for the fabrication of refrigerator cabinets at a plant of one of the industry's largest manufacturers. Twelve photographs illustrate the 11 separate production steps including combination tangent bending and welding, corner seam and toe spot welding, and back spot welding.

For your free copy, circle No. 31 on Reader Information Card.

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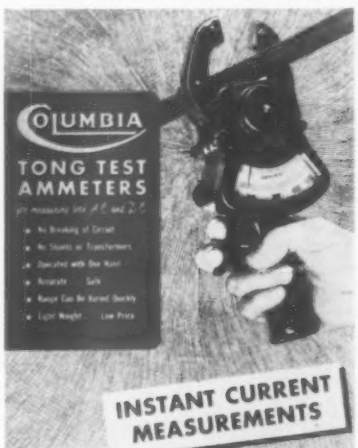
A-C, D-C Ammeters

A new 8-page catalog on its complete line of "Tong Test AC-DC Ammeters" has just been released by Columbia Electric Mfg. Co., 4519 Hamilton Ave., Cleveland 14, Ohio. The new bulletin illustrates eight types of instruments and gives detailed information on the selection, ordering and use of "Tong Test Ammeters," said to be the only clamp-type ammeters that measure both ac and dc. Bulletin includes prices and shipping weights as well as information on the Columbia Type AC-1 volt-ammeter and the new Columbia Model UV-1 a-c, d-c voltmeter, the latter for measuring voltages to 600 v, ac or dc.



For your free copy, circle No. 32 on Reader Information Card.

Ultrasonic Soldering

Ultrasonic fluxless soldering is the subject of new Sonosolder Bulletin SB-5 just released by Aeroprojects Inc., West Chester, Pa.

An illustrated booklet, its eight pages describe the full line of ultrasonic fluxless soldering equipment and its various uses, as developed by Aeroprojects. Models vary from the hand unit to a specialized high production unit, with special tips made to suit individual needs. Sonosolder equipment is used for fluxless soldering of silicon, germanium, aluminum, magnesium and many other materials.

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Five Styles of Hand Torches

Bulletin HT-1, "Selas Hand Torches," which presents a new line of gas-fired, spear-flame hand torches for brazing, soldering, jewelry manufacturing, glass ampoule sealing, dental manufacturing, spot heat treating, laboratory works, glass working and preheating is available from Selas Corp. of America, Dresher, Pa.

Data on the five standard sizes available, which provide heat release from 500 to 29,000 Btu/hr, are included, along with actual size drawings to make selecting easier.

For your free copy, circle No. 34 on Reader Information Card.

Precious-Metal Brazing Alloys

Western Gold & Platinum Co., Belmont, Calif., reveals new proprietary precious metal brazing alloys, namely: Paloro, Nicoro 80 and Nicusil 3 in new 4-page Catalog No. V-124, describing the complete line of Wesgo ultra-high purity, low vapor pressure brazing alloys for vacuum systems.

For your free copy, circle No. 35 on Reader Information Card.

Wall Chart for Steel Bars

An 11- x 17-in. wall chart listing all AISI grades of cold-finished steel bars has been made available by La Salle Steel Co., Hammond, Ind. This new 5-page comparison chart lists 241 grades of steel bars as well as their complete chemical analysis. Machinability ra-

tings are also given in surface feet per minute or as a percentage rating compared to AISI Grade B1112.

The chart covers 8 AISI grades of screw machine steels, 25 AISI grades of resulfurized carbon steels, 64 AISI grades of open hearth steels and 140 grades of alloy steels. Included in these alloy steels are 19 AISI grades which contain boron and 15 tentative standard grades.

For your free copy, circle No. 37 on Reader Information Card.

Steel Specification Guide

A new four-page folder TDC-186, published by the Tubular Products division of the Babcock & Wilcox Co., Beaver Falls, Pa., is a cross reference between the type of steel, the application and the specifications covering the product. ASTM specifications and a number of special B&W specifications covering the products mentioned are included.

For your free copy, circle No. 38 on Reader Information Card.

REVIEWS
OF NEW BOOKS

Aluminum-Welding Training Manual

Kaiser Aluminum Welder's Training Manual. 144-page booklet. Copy obtainable free when requested on company letterhead. Otherwise, $1.00. Published by Technical Publications Dept., Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, Ill.

Material in this publication covers three primary functions essential to aluminum welding. In the first section of the booklet essential factors about both tungsten-inert-gas and metal-inert-gas welding techniques are presented. This introductory information includes descriptive data about aluminum alloys and their characteristics directly associated with welding. In addition, details are given on preparing aluminum for welding which covers joint design for both methods. The types of equipment and supplies needed are listed and described. Numerous tables in this section inform the reader on welding practices, recommended filler material, preheat temperatures where required and similar data.

The second and third sections of the manual offer step-by-step exercises to follow in metal-inert-gas welding. These exercises include in part, setting up the equipment, establishing an arc, forming the weld pool, flat position welding, single and multi-pass welding, making butt and fillet welds, horizontal and vertical welding and making overhead welds. Twelve practical exercises are devoted to tungsten-inert-gas welding and eleven exercises are offered on metal-inert-gas welding.

The exercises suggested are based upon actual practices originated in the company's Department of Metallurgical Research. They are designed to establish an efficient and usable procedure for welding aluminum both in the plant and in the field.

The trainee, upon completion of the exercises with the suggested practice of making welds, is able to qualify within the limits of the two inert-gas welding methods covered.

All exercises are illustrated. Schematic drawings show the work setup for joining parts prior to welding. Holding fixtures, tacking and weld pass sequence are indicated. Photographs showing good and bad welds enable the trainee to evaluate the merit of his own work through visual comparison. Sectional micrographic illustrations clearly show metal-to-metal fusion in the various welds discussed. Methods for preparing such sections, together with instructions for bend testing weldments to comply with established standards, are shown.

For details, circle No. 39 on Reader Information Card

Arc-Welding Manual

Arc Welding by William Sellon, Bemidji State College, and John Matthews, University of Illinois. Revised third edition, 44 pages, 8½ x 11-in. paper-bound book, illustrated with 92 drawings and pictures. Price, 50¢ postpaid in the United States, 75¢ elsewhere. Published by The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio.

This basic manual of instruction explains fundamentals of arc welding and its use in shops, farms or homes. Written for the beginner, the manual is suitable for use in agricultural, vocational and introductory training schools, industrial art shops and for self-instruction. Various chapters in the book treat such subjects as "How Arc Welding Is Used," "Arc Welding Equipment," "Learning to Weld," "Making Welds in All Positions," "The Effect of Heat on Metals," "Cutting with the Arc," "Welding Cast Iron," "Welding Sheet Metal," "Hardsurfacing," and "Projects."

Fire Codes

National Fires Codes, 1958, six volumes, 170 separate standards, 4800 pages, $7.00 per volume. Published by National Fire Protection Association, Boston, Mass.

Important changes in fire safety standards are incorporated in a new and revised edition of the National Fire Codes just published by the National Fire Protection Association.

The 6-volume 1958 edition is a compilation of the 170 standards developed by NFPA in the fields of flammable liquids and gases, combustible solids, dusts, chemicals and explosives, building construction and equipment, extinguishing equipment, electrical, transportation and miscellaneous operations.

New material in the 1958 edition includes 38 new or revised fire safety standards adopted at the 1958 NFPA Annual Meeting. It also incorporates all amendments approved by the NFPA Board of Directors up to and including July 30, 1958.

• WATCH
• WELDING
• JOURNAL
• JANUARY

For details, circle No. 40 on Reader Information Card →

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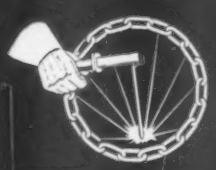

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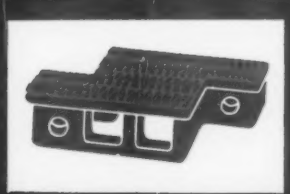
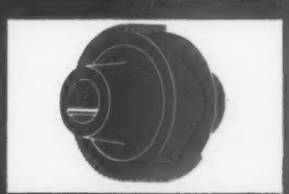
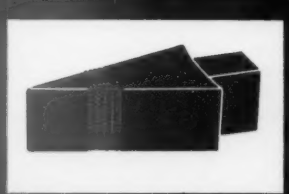


Tractor Rails
TUBE-ALLOY BU WIRE

Ditcher Rollers
TUBE-ALLOY 252



Shovel Rollers
TUBE-ALLOY 258



Shovel Bucket Teeth
TUBE-ALLOY 218

ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,817,745—Tube Butt Welding—Frank J. Pilia, West Orange, and Lloyd W. Young and Stanley H. Royer, Elizabeth, N. J., assignors to Union Carbide Corp., a corporation of New York.

The present patent relates to holding tubular workpieces in abutting end-to-end relation and applying substantially constant welding heat from a torch to the workpiece ends to form a weld puddle. The heat of welding advances conductively in the direction of welding at a rate determined by the characteristics of the tubular ends of the workpieces. The torch device is revolved around the abutted tubular ends to move the weld puddle around such ends at a rate exceeding the rate of conductive heat advance in the workpieces.

2,817,746—Stud Welder—William G. Henderson, Lancaster, Pa., assignor to Radio Corporation of America, a corporation of Delaware.

Henderson's patent relates to apparatus for automatically loading an element into a support member for stud welding action. The new feeding apparatus includes vibrating mechanism attached to a chute to provide vibration thereof relative to the support member provided.

2,817,747—Method and Apparatus for Electric Resistance Welding—William H. Devonshire, Williamsville, Thomas A. Wilson, Kenmore, and Humphrey F. Parker, Buffalo, N. Y., assignors to McKinnon Chain Corp., Tonawanda, N. Y.

The present patent relates to a resistance welding machine of the type having a source of welding current and grid-controlled discharge device means therein for regulating the effective magnitude of the welding current. Additional means are provided and include a member for generating a pattern signal representing a desired temporal variation in the temperature of material being welded and means responsive to the radiance of material being welded for generating a signal representative of the instantaneous temperature of the material due to the passage of the welding current therethrough. Other control means are provided responsive to the instantaneous difference in magnitude of the signals for controlling the discharge device means.

2,817,748—Welding Process—Amel R. Meyer, Griffith, Ind., assignor to Graver Tank & Mfg. Co., Inc., East Chicago, Ind., a corporation of Delaware.

This patent relates to a process for welding vertical abutting edges of upright, stationary metallic plates and wherein the edges are beveled to form a trough. The process covers steps of rolling a compressible refractory strip upwardly on the plates in overlying relation to the edges and depositing a bed of flux on the strip. Welding wire is fed through the flux bed into a zone that is held temporarily stationary relative to the plates by the refractory strip and moving the welding wire upwardly in association with the rolling action of the strip. Welding heat is fed through the welding wire to the plate to form a molten pool in the trough and concurrently with the feeding of the welding heat and vertical motion of the welding wire, the wire is oscillated transversely of the edges to be welded to direct a major portion of the welding heat along the edges of the trough.

2,817,749—Flexible Nozzle for Welding—John J. Flood, West Medway, and Edward L. Pulnik, Lawrence, Mass.

This welding run includes a flexible barrel, a coaxial electrically insulating flexible liner tube and an electrically conducting guide at the discharge end of the tube. Welding wire is fed through the tube and guide and an electric cable is outside and separate from the barrel, but connected to the guide to complete the circuit through the welding wire.

2,817,751—Welding Electrode—Charles E. Phillips, Detroit, Mich.; Charles A. Dean, executor of the estate of said Phillips.

Phillips' patent covers a welding electrode made from a copper core surrounded by an annular steel sheath of substantially equal amount by weight. An exterior flux coating is provided on the steel sheath.

2,818,352—Welding Electrodes—Howard C. Ludwig, Pittsburgh, and Julius Heuschkel, Irwin, Pa., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

In this patented electrode, a ferrous electrode directed to the making of high ductility welds by an inert-gas-shielded welding action is disclosed. The electrode has a coating consisting essentially of at least one oxygen containing compound selected from the class consisting of metal oxides, metal carbonates and metal phosphates. The electrode has a core of an alloy made from an iron base and small quantities of carbon, manganese and silicon. The carbon, manganese and silicon have a formula relationship to each other by weight.

2,818,353—Electric Arc Welding Electrode—Howard C. Ludwig, Pittsburgh, Pa., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

Ludwig's patent is on a ferrous welding electrode and it includes a steel wire core having a diameter of the order of 0.062 in. and having an arc stabilizing coating of the order of 2 to 5 mg. per ft of electrode. This coating primarily comprises specified portions of titanium dioxide, manganese dioxide and calcium oxide.

2,818,488—Tube Welding—Wallace C. Rudd, Larchmont, and Robert J. Stanton, Brooklyn, N. Y., assignors to Magnetic Heating Corp., New Rochelle, N. Y., a corporation of New York.

This patent relates to the welding together of the edges of a longitudinal gap in metal tubing and in the process the tubing is longitudinally advanced while subjecting it to pressure from opposite sides to bring the gap edges together at a welding point as a narrow V-shaped formation. The edges of the tube are heated to welding temperature by contacts connecting to means providing a source of high-frequency current. These contacts are applied to points of the tubing on opposite sides of the gap at a position shortly in advance of the welding point. Welding contacts and current are set up so as to conduct the current along and just above the V-shaped formation at the tube edges to decrease the reactance of this current flow path.

2,818,489—Tube Welding by High Frequency Resistance Heating—William C. Kalning, Metedeconk, N. J., and Robert J. Stanton, Brooklyn, and Wallace C. Rudd, Larchmont, N. Y., assignors to Magnetic Heating Corp., New Rochelle, N. Y., a corporation of New York.

The present apparatus relates to the welding together of a pair of approaching metal edges as they are being longitudinally advanced. The feature of the patent relates to the use of a spreader element of ceramic material which has side edges in sliding engagement by the edges of the metal being formed within a tube and adjacent a weld point therefor. This ceramic spreader element is positioned a predetermined amount in advance of the welding point for the adjacent tube edges.

2,818,492—Pneumatically Operated Welder Head Construction—William L. Komph, Sr., Port Huron, Mich., assignor to The Wellman Engineering Co., Cleveland, Ohio, a corporation of Ohio.

Komph's patent is on a welding device for positioning an electrode. This device includes a cylinder having a piston member slidably mounted therein and an electrode carried by the piston and having a welding tip offset from the axis of the piston and cylinder. Other special means control the action of the piston in the cylinder for positioning the electrode.

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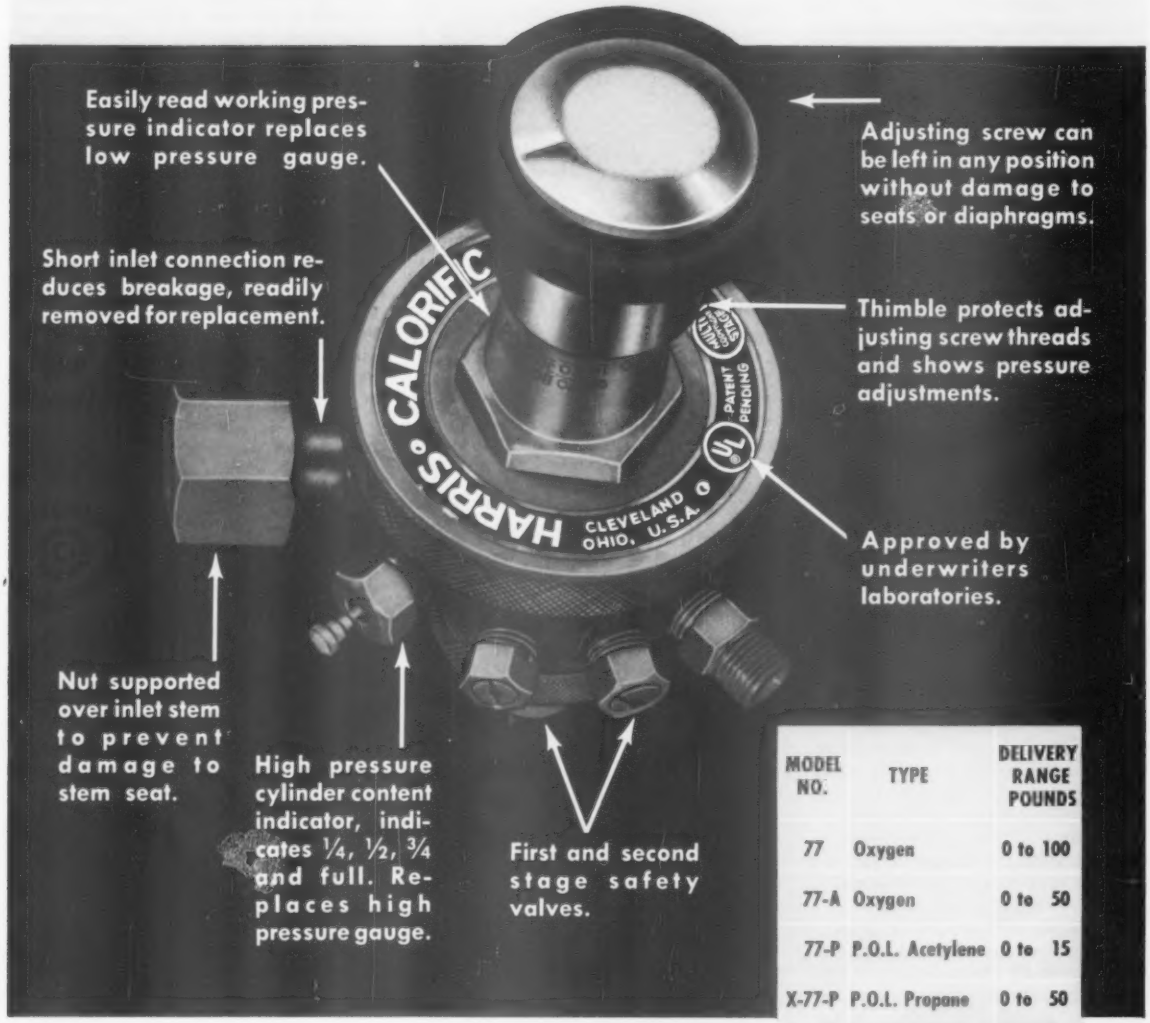
Easily read working pressure indicator replaces low pressure gauge.
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Nut supported over inlet stem to prevent damage to stem seat.
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77-P	P.O.L. Acetylene	0 to 15
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77-D	Coml. Acetylene	0 to 15
X-77-D	Coml. Propane	0 to 50

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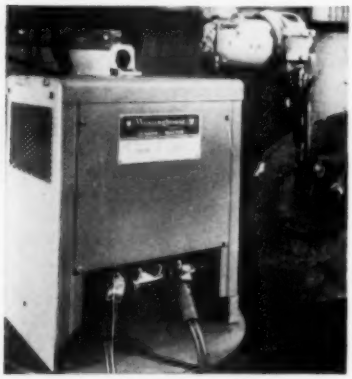
For details, circle No. 45 on Reader Information Card

NEW PRODUCTS

Development in CO_2 Welding

Research by the Westinghouse welding department into the electromechanics of weld-metal transfer in gas-shielded welding processes has led to a new type of power supply equipment that will bring the advantages of CO_2 welding to many new industrial applications. Suitable for use with any standard constant-potential, constant-wire-speed system of metal-arc inert-gas welding, the new "Dynamic Reactors" are compact, static, two-terminal packages that are connected in series with either of the welding current leads; physically, the units can be placed near the welding machine or near the work.



By limiting the rate of rise of weld current, the new reactors permit the use of lower weld currents and the transfer of weld metal in droplet form. In turn, lower currents and droplet transfer permit the use of larger and less expensive wire sizes, effective depth control of weld penetration and the use of the CO_2 process for vertical and overhead welding.

Basically, the new development grew from recognition that the high welding currents normally characteristic of the CO_2 process were necessary to prevent creation of globules of molten metal capable of short-circuiting the arc. When such short circuits occur, the constant-potential power source produces very high currents whose magnetic forces can disrupt the globules and throw them from the arc region as spatter.

The new dynamic reactor inhibits the growth of these short-circuit currents and thus allows the weld metal to be melted for smooth transfer to the pool on the workpiece.

When applied to automatic and semiautomatic welding equipment, Westinghouse officials cite the new reactor makes it possible to reduce minimum welding current by a factor of more than two to one. In a typical process using $^1/_{16}$-diam wire, minimum current can be reduced from the conventional value of 300 to about 100 amp, with negligible spatter and the ability to weld in any position.

Reductions in weld current ranges will also give the CO_2 process the ability to join thinner metal than formerly was practical. Where weld penetration depth once limited the process to $^1/_8$-in. material (with a copper backing plate), the new technique is said to permit butt welds without backing plate on 0.040-in. material with electrodes of the same size as used for 0.125-in. material.

Units rated at 150/300 amp require one square foot of floor space, stand 19 in. high and weigh 118 lb. Units rated at 300/600 amp are 18 in. wide, 13 in. deep, 26 in. high and weigh 220 lb.

For more details, circle No. 41 on Reader Information Card.

Welding Carbon Products

A complete line of welding carbon products is now being sold by the Arcair Co., Lancaster, Ohio, through its retail sales outlets. The Arcair Co. manufactures and distributes metal removal torches and special cutting and gouging electrodes used with the torch. Until recently these two lines were sole products handled by the organization.

The welding carbon products' line includes a-c welding electrodes, carbon plates, carbon rods and carbon paste.

For more details, circle No. 42 on Reader Information Card.

Protective Coating

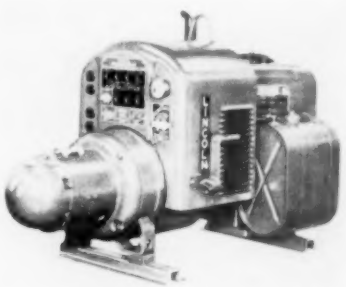
A new process for providing sheet metal parts with a furnace-bonded protective coating, which resists oxidation, abrasion and corrosion, has been announced by Stainless Processing Division, Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich. Named the Nicrocoat process, the new method can reportedly impart to mild steel and other low-cost metals oxidation and corrosion resistance usually found only in stainless steels and other high-alloy metals, while at the same time providing abrasion resistance better than stainless steel.

The Nicrocoat process is the result of more than 3 years of development work by Wall Colmonoy's research laboratories. It consists of applying a superthin coating of a special metal alloy to the base metal requiring protective following fabrication. The alloy is then bonded to the base metal by heating to a specified temperature under controlled conditions in a pure dry-hydrogen atmosphere furnace.

For more details, circle No. 43 on Reader Information Card.

200-amp Auxiliary Unit

A new combination a-c power supply and arc welder has been announced by the Lincoln Electric Co., Cleveland 17, Ohio. The new "Weldanpower" machine serves as 5-kva power supply for use in the event of commercial power failure or where commercial power is not available. In addition, "Weldanpower" is a 200-amp a-c welder.



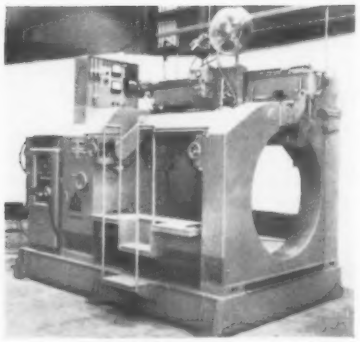
"Weldanpower" has a heavy-duty, Wisconsin air-cooled, 4-cycle Model TFD engine. It delivers 13.1 hp at 2000 rpm.

The "Weldanpower" provides 115- or 230-v, 60-cycle, a-c single-phase power. It is rated 5 kva, continuous duty. Maximum continuous current at 230 v is 18.2 amp.

For more details, circle No. 44 on Reader Information Card.

Automatic Welding of Flats and Tubes

Berkeley-Davis Inc., 1021 Bahls St., Danville, Ill., have developed a precision, longitudinal seamer capable of welding flat sheets or tubular sections up to 4 ft diam and 4 ft in length and from 0.005 to $^1/_2$ in. thicknesses. The 17,000-lb machine, 8 x 8 x 10 ft, contains a $^1/_3$-hp motor-driven travel carriage operative on tool steel track, the latter



adjustable in horizontal and vertical planes. Mandrels are equipped with backing bars which carry argon in a distributing manifold.

The welding equipment is mounted on the base of the machine and consists of a high-frequency power source with up and down slope, and a wire feeder and torch assembly.

For more details, circle No. 46 on Reader Information Card.

Large Positioner

According to the Plainfield, N. J. plant of Worthington Corp., the world's largest positioner has been shipped to

Bucyrus-Erie of Milwaukee, producer of some of the largest shovels on the market.

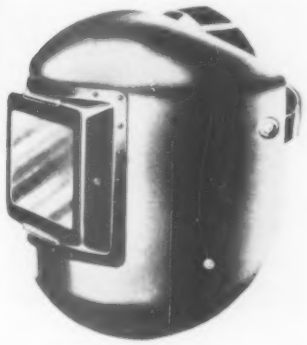
With a capacity of 200,000 lb at 24-in. center of gravity and 24-in. eccentricity, the machine stands 13 ft 9½ in. high with table horizontal, is 19 ft wide at the base with two base pads 11 ft 4 in. long and 3 ft 8 in. wide, and has 50 hp on tilt.

To be utilized by Bucyrus-Erie for welding large frames for power shovels, the Worthington positioner uses two synchronized 25-hp motors to drive the tilt. Normally this is done with a single motor and cross shafts to supply power to the tilt gears.

For more details, circle No. 47 on Reader Information Card.

Wide-Vision Welding Helmet

Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y., has announced the availability of a new wide-vision welding helmet which is said to offer a 120% increase in the welder's field of vision. The lens area measures 4½ x 5¼ in., an asset to those who must wear bifocal or trifocal prescription glasses beneath the helmet.



The two models, one with a curved bottom going under the chin and the other with the bottom extending straight down to the chest, accommodate lens shades 3 through 14, all meeting federal specifications. The helmet is constructed of vulcanized fiber and is of seamless design.

For more details, circle No. 49 on Reader Information Card.

Acetylene Cylinder Improved

Norris Thermador Corp., 5215 S. Boyle Ave., Los Angeles 58, Calif., has completed seven years' research on the development of the firm's new acetylene cylinders. The modified Lime Silica filler is said to provide 15% increase in gas capacity and a 7% reduction in weight. Cylinders are now available with 10 to 350 cu ft capacity. Reported to take a fast charge, the cylinders show no loss of acetone.

For more details, circle No. 50 on Reader Information Card.

Low-Pressure Regulator

A new line of single-stage inverse-type station regulators for low-pressure service, the Airco 9900 Series, has been announced by Air Reduction Sales Co., a Division of Air Reduction Co. Inc., 150 E. 42nd St., New York 17, N. Y. Because of low friction in the internal mechanism, and large effective area of the flexible diaphragm used, these regulators are said to provide accurate pressure regulation with little fluctuation in delivery pressure. They are designed for handling an inlet pressure up to 300 psi.

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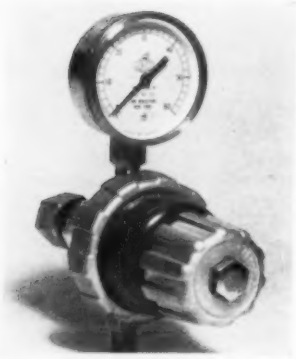
For details, circle No. 48 on Reader Information Card



The regulator body is a machined brass forging with a hexagon section that simplifies disassembly. The spring case is aluminum which fastens to the regulator body by a forged brass retaining ring.

For more details, circle No. 52 on Reader Information Card.

Resistance-Welder Controls

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., have announced a new design of the Model SWC-2X single-phase resistance-welder control. The new control is composed of the timing panels, the firing panels and the ignitron contactor panel. Transistors and printed circuits are used in the timing and firing panels. Sciaky is reported to have simplified the elements in the electronic control by designing the transistors to function as switches rather than substitutes for vacuum tubes. The new concept is said to provide a more precise and rapid sequence in single-phase control for resistance welders.

For more details, circle No. 54 on Reader Information Card.

Safety Goggles

Bausch & Lomb Optical Co., Rochester 2, N. Y., announces a new line of cup-type safety goggles which includes eight new models designed specifically for heavy industrial operations.

Highlighting two models of the new line is a removable soft sponge face pad which is exclusive with Bausch & Lomb.

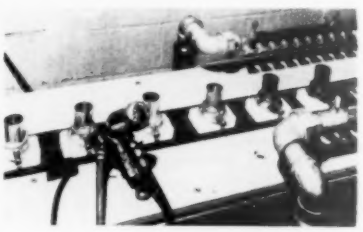
The four new chipper-type goggles have heat-treated "Bal-SAFE" lenses and new perforated side shields for ventilation. Adjustable head band is standard equipment.

New cup-type goggles for welders feature "Arc-Ban," a dark green glass which provides protection from harmful infrared and ultraviolet rays. Newly designed side shields guard the eyes against sparks and side flashes.

For more details, circle No. 55 on Reader Information Card.

Production Silver Brazing

High speed, production silver brazing of component parts is reportedly possible using a new process developed by Fusion Engineering, 17921 Roseland Ave., Cleveland 12, Ohio.



This process automatically pre-places the brazing alloy and flux onto the parts while on the production line. Automatic heating devices then complete the brazing operation. Quality of the soldered joint is said to be held absolutely constant.

For more details, circle No. 56 on Reader Information Card.

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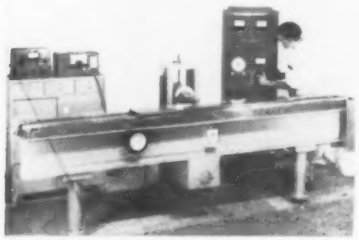
For details, circle No. 53 on Reader Information Card

Ultrasonic Seam Welder

Aeroprojects, Inc., West Chester, Pa., have introduced a continuous ultrasonic roller-type seam welder. On this particular unit the work passes under the ultrasonic welding tip which, in turn,



rotates and supplies uninterrupted ultrasonic power, thus producing a continuous weld. The complete starting cycle is automatically controlled and can reportedly be actuated by a foot pedal.

For more details, circle No. 57 on Reader Information Card.

Flux-Coated Bronze Welding Rod

Aufhauser Brothers of Albertson, Long Island, in N. Y., and Toronto, Canada, have developed a new all-purpose, flux-coated bronze welding and brazing rod for oxyacetylene welding and brazing.

The new rod is made of degasified, deoxidized, very low-fuming bronze, to which a special coating has been applied. Although free flowing, it retains sufficient viscosity to enable the operator to control the molten deposit.

It is intended for braze-welding metals with higher melting points such as steel, cast iron or malleable iron; for fusion welding of brass, bronze and copper alloys; and for building up wearing surfaces.

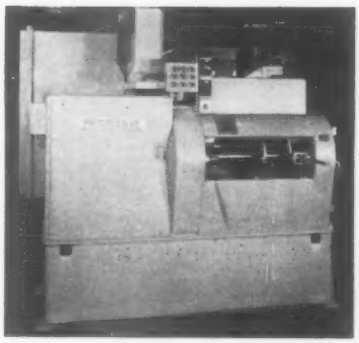
For more details, circle No. 58 on Reader Information Card.

Automatic Arc-Welding Machine

The Special Machinery Division, Progressive Welder Sales Co., Pontiac, Mich., has just completed the building of an automated arc-welding machine for the welding of transmission shafts to carrier cases with a complete cycle time of 12 sec per piece.

According to the manufacturer, the new machine automatically accomplishes the welding of two dissimilar alloy pieces, which have been preground and finished to accurate dimension, with no measurable change in tolerance.

This compact welding machine has four rotating fixtures individually mounted in precision bearings in a vertical rotating head. Head and fixtures are hydraulically driven through a non-locking worm-gear drive.



For more details, circle No. 59 on Reader Information Card.

Heavy-Duty Spot Welder

A general purpose heavy-duty press-type spot welder, introduced by the Federal Machine and Welder Co., Warren, Ohio, is said to embody a special frictionless air head and slide unit. It has an 8-in. diam, 3-in. stroke operating cylinder, 18-in. throat depth, 100-kva welding transformer with 8 steps of heat regulator plus series-parallel connection. Transformer and heat regulator are combined in an integral unit. Controls are built into the one-piece welded steel frame and upper arm. It has universal arms and a closed water-cooling system. Foot switch starts automatic weld sequence.

For more details, circle No. 60 on Reader Information Card.

Silver-Brazing Alloy

A lithium-containing silver-brazing alloy, known as Fluxless Nu-Braze #0070, has been introduced by American Silver Co., 36-07 Prince St., Flushing 54, N. Y. To join such metals as precipitation-hardening stainless steels and other aircraft steels designed for applications at high temperatures, the new brazing alloy is recommended on structural parts whose operating tempera-

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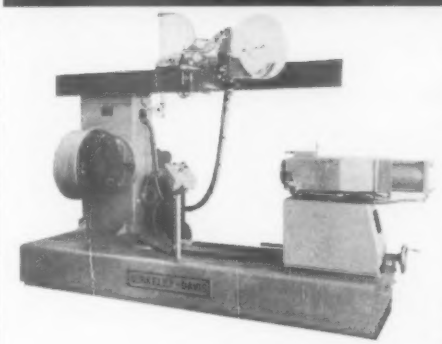

UNIVERSAL ROTATOR

with Tilting Headstock

Another first in the industry by Berkeley-Davis allows rotary seams to be welded in any required position within the rotator's capacity. The tilting headstock can convert the Universal Rotator into a welding positioner. The Universal Rotator accepts parts up to 48" diameter, 24" to 6' in length. Other lengths available upon request.

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For details, circle No. 61 on Reader Information Card

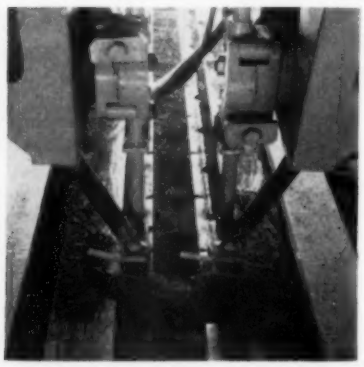
tures reach 900° F. The alloy has a melting range of 1435 to 1635° F. Its composition consists of 0.20% lithium, 92.5% silver and the balance copper.

For more details, circle No. 62 on Reader Information Card.

Dual-Head Track Welder

Equipped with dual automatic welding heads, an automatic track-link welding machine is now available from L and B Welding Equipment, Inc., 2424 Sixth St., Berkeley, Calif.

Designed for service shops maintaining crawler-mounted equipment, floor-to-floor time for building up both sides of a complete set of D8 tracks with 1/4-in. worn depth is said to be 14 hr with a single operator.



Features of the new unit include a patented electric template, flux-handling hoist operating over full length of track and built-in automatic wire-feed adjustment. An automatic positioner for roll and idler welding is available as an attachment.

The unit includes a constant-potential, 100% duty cycle power supply providing two 500-amp circuits for the dual welding heads.

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Radio-Frequency Generator

A new totally enclosed industrial radio-frequency generator with a minimum output rating of 25 kw at a nominal frequency of 450 kc is announced by Welduction Corp., 10230 Capital Ave., Detroit 37, Mich. Designated Model IH-25, this generator is used to supply radio-frequency power for metal hardening, drawing, melting and brazing applications.

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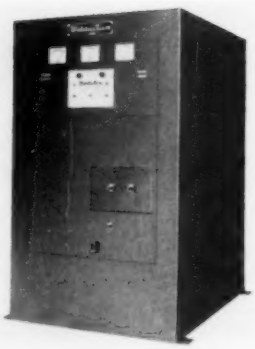

section. Grid keying of the oscillator tube prevents contactor wear. Telltale lights and multi-color meters with proper operating ranges give indication of operating irregularities. The generator is said to meet all requirements of the FCC and is in a NEMA type 12 enclosure.

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Reflectoscope

A new reflectoscope, the Model UR-600, has been introduced by Sperry Products, Inc., of Danbury, Conn.

The company reports that the UR-600 incorporates advanced pulser and receiver circuitry assuring greater sensitivity, and higher resolution at no sacrifice of linear response or dynamic range.

A variable pulse repetition rate facilitates high speed scanning of small parts. Brighter video trace on the edge-lighted CRT screen makes for easier reading in daylight with faster interpretation of indications.

The instrument may be used for both contact and immersion testing with one or two search unit techniques. It may be fitted with an automatic alarm system by adding the Sperry RA Monitor.

Self-contained in an aluminum case, the UR-600 weighs 75 lb.

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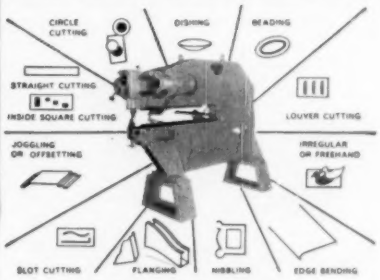

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Press-Type Spot Welder

Peer, Inc., Benton Harbor, Mich., has introduced a hand-operated 1-kva spot welder in 110- or 230-v capacities (60 cycle, single phase). With 9 x 15 x 14 1/2 in. dimensions, it weighs 65 lb.

Model R-600 is a press-type precision welder. Pressure is applied in a straight line, while cam-lever action reportedly produces required high pressure.

For more details, circle No. 68 on Reader Information Card.

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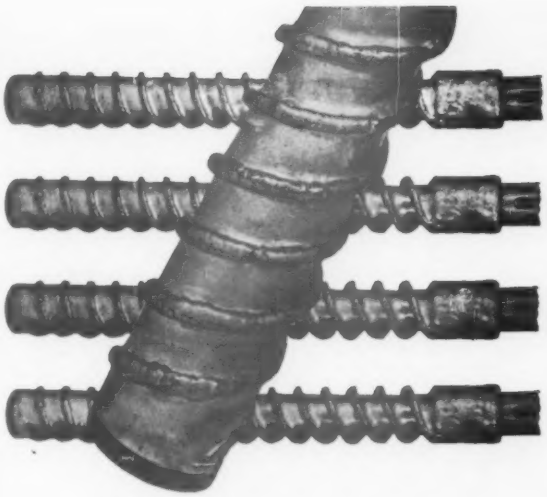

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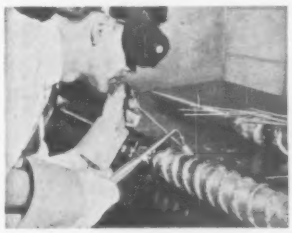

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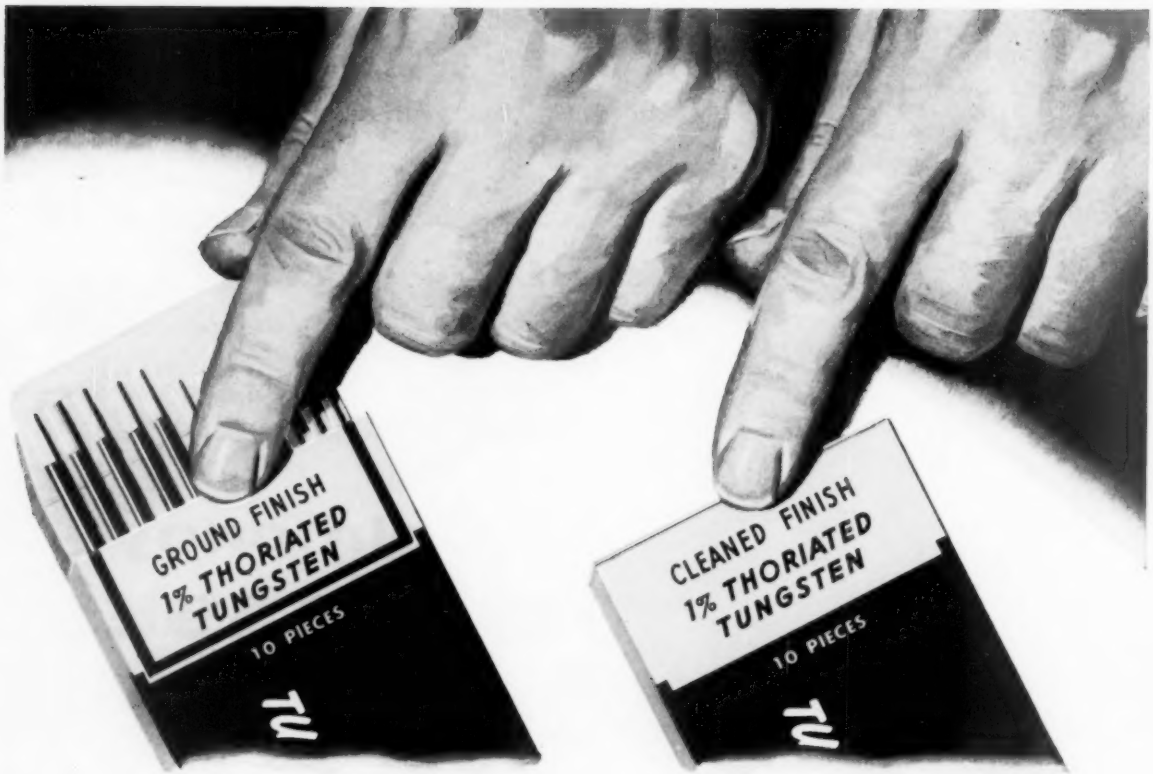

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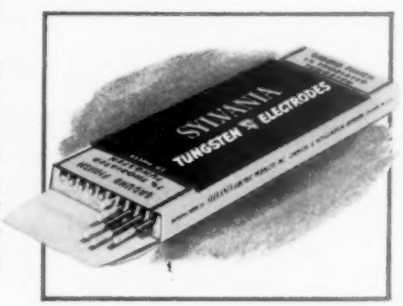

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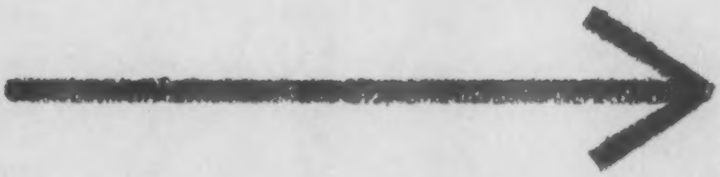

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JOINING OF ZIRCALOY TO STAINLESS STEEL

Investigation undertaken to develop a zirconium-to-stainless-steel joint in heavy-wall tubing, the joint to incorporate a metallurgical seal which would not be attacked during long exposure to pressurized high-temperature water

BY J. B. McANDREW, R. NECHELES AND H. SCHWARTZBART

ABSTRACT. The work reported was undertaken for the purpose of developing a zirconium-to-stainless-steel joint in heavy-wall tubing, the joint to incorporate a metallurgical seal which would not be attacked during long exposure to pressurized high-temperature water.

Flash welding and brazing were the joining methods investigated. Some weldments and brazements showed promise of meeting the requirements, but reproducibility of performance among different joints was poor in both cases. Thermally engendered stresses were a major source of difficulty, whereas it appears that the corrosion problem is not insoluble.

Introduction

Two materials having properties highly useful for the construction of pressurized-water nuclear-power reactors are Type 347 stainless steel and the zirconium-base alloy Zircaloy-2. In order to obtain maximum benefit from the properties of each in certain applications, a joint must be fabricated between the two alloys in the form of heavy-wall tubing. Furthermore, the joint must function with a high degree of reliability over a long period of time, must provide a high-pressure seal, and must be resistant to corrosion in an environment of high-temperature water. These considerations prompted an investigation of brazing and welding as methods of joining these two dissimilar alloys.

J. B. McAndrew, R. Necheles and H. Schwartzbart are associated with Metals Research Department, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

The principal difficulties expected were related to: (1) the poor mechanical and corrosion properties of highly alloyed zirconium-iron, which ruled out ordinary fusion welding and added to the difficulties of other welding methods; (2) the large difference between thermal expansion coefficients of the two alloys; and (3) lack of brazing filler metals capable of forming brazements with the necessary corrosion resistance.

Attention was directed primarily toward the achievement of corrosion-resistant metallurgical seals; unless this objective could be attained, it would be futile to devise methods of overcoming the problems associated with thermal stresses and mechanical strength. Two possibilities were envisioned. Flash-butt welding might prove to be successful, since the fused material may be rather effectively expelled from the joint region by this process. Or, alternatively, it might be found feasible to develop brazing alloys with the requisite properties. Both of these possibilities were experimentally explored. The brazing-alloy development was carried on in conjunction with a similar study directed toward finding suitable alloys for brazing Zircaloy to Zircaloy.[1]

Experimental Methods

An accelerated corrosion test was required which would provide a rough evaluation of various experimental joints. The test environment selected was static distilled water at 680° F (360° C), and it was estimated that an exposure of 1200 hr without resultant serious attack would indicate sufficient corrosion resistance to recommend further study. The tests were intermittent in that specimens were removed from the autoclave for examination at intervals varying from a few to several hundred hours. Specimens were removed from test only after cumulative exposure of at least 1200 hr or if complete separation of the joined members occurred. The condition of specimens which survived the test without total failure was evaluated by breaking the joint apart and observing the fracture surfaces.

Several types of specimens were prepared.

(1) Flash-welded bars $^1/_4$ in. sq x 3 in. long.
(2) Flash-welded heavy-wall tubing.
(3) Flash-welded flanged heavy-wall tubing (Fig. 1*a*).
(4) Brazed single-lap joints between bars 3 x 1 x $^1/_4$ in., with a lap of about $^3/_8$ in.
(5) Butt-brazed heavy-wall tubing.
(6) Butt-brazed flanged heavy-wall tubing (Figs. 1*a*, 1*b*, 1*c*).
(7) Brazed sleeve joints in heavy-wall tubing, with and without auxiliary threads (Figs. 1*d*, 1*e*).

Of these, corrosion tests were performed on specimens of types 1, 2, 4 and 5.

Flash welding of the small bars was performed on a 75-kva flash-butt welder. For heavy-wall tubing, the machine used was a 500-kva flash-butt welder.

All brazes were made by induction heating in inert atmosphere. In most cases the filler metal was placed outside the joint rather than being preplaced between the faying surfaces. No flux was used. Heating was controlled manually according to visual observation of the specimen and was continued only until filler-metal flow and filleting were evident. The lap-joint corrosion specimens were at first brazed by lightly clamping the steel and Zircaloy together. In later work with the more promising alloys, a 0.003-in. molybdenum shim was used to maintain a definite spacing between the two members.

Two methods were used for preparation of experimental brazing alloys. Alloys containing highly reactive or refractory metals were arc-melted in water-cooled copper crucibles using a helium atmosphere. Other melts were carried out by induction melting in alumdum crucibles with a helium atmosphere.

Experimental Results

Brazing

Nominal compositions of the brazing alloys used in this investigation are listed in Table 1. Not all of these were successfully used as filler metals. Spontaneous fracture after cooling occurred with the aluminum-base alloys, with Cu – 37.5% Au, and in one case with 0.001-in. plated Ni – 7%P. Also, the Pd – 20% Sn alloy apparently had too high a flow temperature to form a braze. Many of these filler metals were eliminated from further consideration because of poor performance in the initial corrosion test. Complete failure of various brazements was observed after exposures of four to several hundred hours. In other cases, although failure was not complete, attack was so severe as to discourage further investigation of the alloys involved.

Encouraging results were obtained with Cu – 20% Pd – 3% In, Ni – 20% Pd – 10% Si, Ni – 30% Ge – 13% Cr, Ni – 40% In, Ni – 7%P, Zr – 5% Be, Zr – 15% Pd – 5% Nb, Zr – 30% Fe – 10% Mn, and Zr – 10% Fe – 10% Cr. Other alloys which showed some attack, mostly localized in the fillet region, were Cu – 7% P, Cu – 3.5% P, Nb – 10% Pd, and Zr – 10% Fe – 10% Sn.

The alloys used to prepare spaced-joint brazements are noted in Table 1. Corrosion tests of these brazements indicated that, in some cases, the effects of cracking due to thermal stresses

Table 1—Nominal Compositions of Brazing Alloys Investigated

Ag – 28Cu (BAg – 8)
Ag – 27Cu – 13In
Ag – 30Cu – 10Si
Ag – 30Cu – 10Sn
Ag – 10In
Ag – 15Mn

Al – 1Ni
Al – 6.2Cu
Al – 24Pd
Al – 10Si – 4Cu

Au
Au – 10Co

Cu – 3.5P*
Cu – 7P (BCuP – 2)
Cu – 37.5Au
Cu – 15Ag – 5Sn – 5P*
Cu – 15Ag – 10Sn – 5P*
Cu – 20Pd – 3In*
Cu – 18.5Pd – 4.5In
Cu – 20Pd – 3In – 7Zr
Cu – 20Pd – 3In – 37Zr
Cu – 20Pd – 3In – 3Ni – 3Fe
Cu – 20Pd – 3In – 3Fe – 3Sn
Cu – 20Pd – 3In – 7 Stainless 347

Nb – 50In
Nb – 10Pd
Nb – 44Ni – 10Zr
Nb – 44Ni – 10Si
Nb – 46.4Ni – 5Si
Nb – 46.4Ni – 5Pd
Nb – 44Ni – 10Pd

Ni – 3.4P
Ni – 7P*
Ni – 20Pd – 10Si*
Ni – 30Ge – 13Cr (G.E.75)*
Ni – 20Cr – 10Si (G.E.81)
Ni – 18In
Ni – 36In – 10Pd
Ni – 40In*

Pd – 40Ni
Pd – 6Si
Pd – 10Nb
Pd – 20Sn

Sn

Zr – 21Cu
Zr – 17Ni
Zr – 27Ni
Zr – 15Ni – 10Sn
Zr – (2.5, 3, 3.5, 4, 4.5, 5,* 5.25, 5.50, 5.75, 6) Be
Zr – 10Fe – 10Pd*
Zr – 30Fe – 10Mn
Zr – 10Fe – 10Cr*
Zr – 15Pd – 5Nb
Zr – 15Fe – 15Mn
Zr – 10Fe – 10Sn

* Compositions used for spaced-joint brazements.

Table 2—Corrosion-Test Results for Zircaloy-to-Stainless-Steel Brazed Tubing

Specimen no.	*Filler-metal composition, wt %*	*Hours tested*	*Remarks*
7-3	70Ni – 20Pd – 10Si	1475	Specimen was thermal cycled 124 times between 300 and 500° F before corrosion test
7-5	70Ni – 20Pd – 10Si	495	Failed—specimen was given diffusion heat treatment of 850° C for 24 hr before corrosion test
7-6	70Ni – 20Pd – 10Si	662	Failed
14-2	57Ni – 30Ge – 13Cr	96	Failed—specimen was thermal cycled 124 times between 300 and 500° F before corrosion test
14-4	57Ni – 30Ge – 13Cr	1475	Specimen was given diffusion heat treatment of 850° C for 24 hr before corrosion test
31	77Cu – 20Pd – 3In	136	Failed
31-1	77Cu – 20Pd – 3In	1390	75% of joint periphery showed voids after 370 hr
31-2	77Cu – 20Pd – 3In	136	Failed
31-3	77Cu – 20Pd – 3In	711	Failed
34-1	95Zr – 5Be	1356	Specimen was thermal cycled 202 times between 300 and 500° F which resulted in a small crack prior to corrosion testing
34 F-4	Zr – 2.5Be	1356	
50-1	77Cu – 18.5Pd – 4.5In	92	Failed—filler metal was preplaced
50-2	77Cu – 18.5Pd – 4.5In	1356	
50-5	77Cu – 18.5Pd – 4.5In	1475	Specimen was given diffusion heat treatment of 850° C for 24 hr before corrosion test

were superimposed on the effects of the corrosive environment. The only alloy which consistently (five specimens out of five) showed a high degree of resistance to both the cracking and corrosion was the nominal Zr – 5% Be. One specimen brazed with Ni – 20% Pd – 10% Si was very good, but duplicates were poor. A single specimen brazed with Cu – 37% Zr – 20% Pd – 3% In, showed only a mild peripheral attack after 1428 hr exposure. Partial failures were observed for each of six specimens brazed with Cu – 20% Pd – 3% In, and it is though that these were caused by thermal stresses.

The suspicion that thermal stresses might have been sufficiently high to play a part in failures observed during corrosion testing of the above samples was strengthened when brazements were prepared with heavy-wall tubing. Of forty-eight butt-brazed joints prepared with seven different alloys, nearly half broke apart from thermal stresses, either spontaneously or with light handling. Of the specimens which remained intact, fourteen were corrosion tested, some after diffusion treatment or thermal-cycling tests. The performance of these specimens was poor, as may be seen in Table 2 and Fig. 2; however, specimens 50-2 and 34F-4 were sound after 1356 hr exposure.

The tendency toward thermal-stress damage was intensified when the stainless-steel member was prepared with an integral, heavy flange at the butt joint (Fig. 1*b*). Of fourteen brazements prepared with this geometry, all cracked spontaneously during or after cooling to room temperature. However, a single specimen with a somewhat narrower flange, which was set back $^3/_8$ in. from the joint (Fig. 1*a*), did not crack.

Another modification of the flanged joint incorporated an annular lip $^1/_4$ in. long by approximately 0.2 in. thick on the stainless-steel member (Fig. 1*c*). The Zircaloy tube was machined to fit inside this annular lip, so that a short sleeve joint was formed. Four of these were brazed, but, again, cracking was observed.

A straight sleeve joint was tried next, with the stainless steel external to the Zircaloy (Fig. 1*d*). Of six such brazements (made with Zr – 3.9 to 4.5% Be) none was free of cracks in the fillet.

Finally, six specimens were prepared which were similar to those just mentioned except that the sleeve was threaded for most of its length, with only the outermost $^1/_4$ in. reserved to form a brazed seal (Fig. 1*e*). Nearly all of these showed some degree of cracking in the fillet, although in some cases this was very slight, and one brazement did not show any cracks.

Flash Welding

A considerable number of variables are under the control of the machine operator during the making of a flash-welded joint. In the interest of saving space, and because very limited interest is anticipated in the details of machine settings used for various specimens, those data will not be reported here.

A group of bars of Zircaloy and stainless steel, each $^1/_4$ x $^1/_4$ x 3 in. long, were flash-butt welded to form specimens for metallographic examination and corrosion testing. Three of these were subjected to tensile test without removal of the flash; the strengths of these three welds were approximately 28,000, 38,000 and 44,000 psi based on the original cross section.

Four specimens were trimmed of flash, lightly pickled and exposed to 680° F water for 1255 hr. One suffered a very small region of attack at a corner, while the other three showed no visible corrosion. One of the latter was then broken in impact with a 50 in.-lb capacity machine. The (unnotched) Charpy impact strength for this bar was 6.4 in.-lb, and the break occurred at the Zircaloy-stainless steel interface, which was at the midpoint of the bar. The dimensions of this particular specimen were 0.260 x 0.233 x 1.509 in.

Three of the four corrosion specimens were subsequently treated in sealed bulbs at 875° C for 24 hr to permit diffusion to occur. Two of these were returned to the autoclave and were found

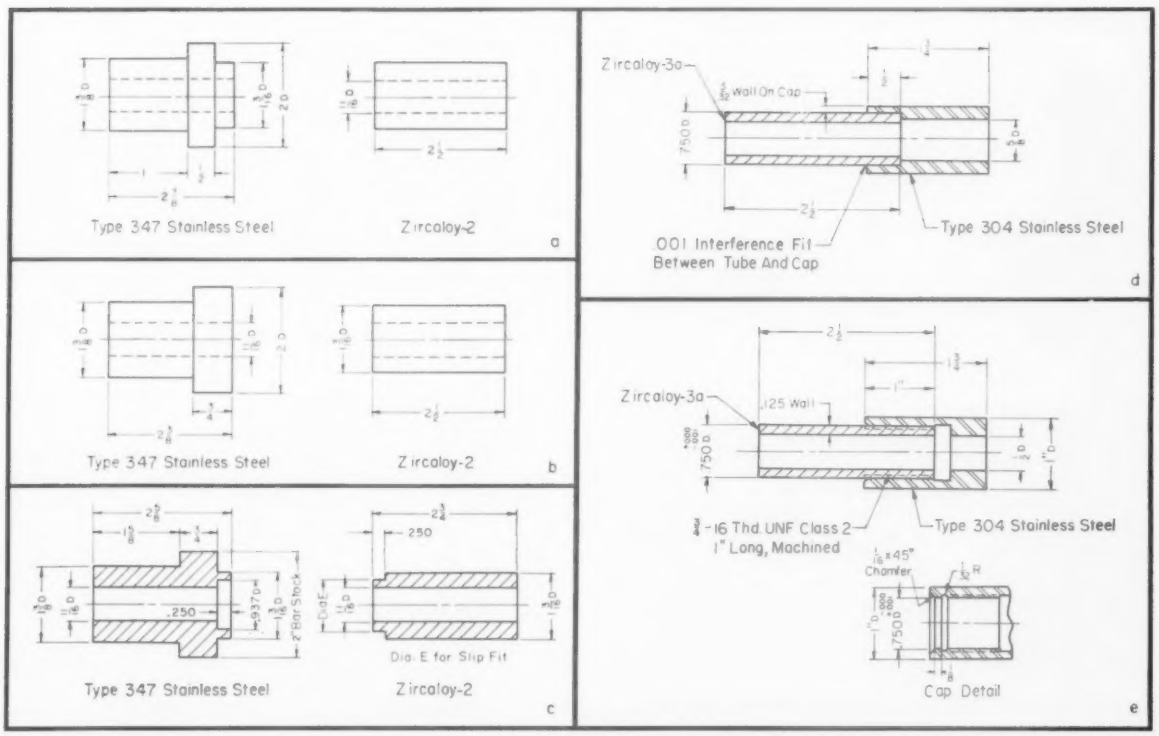
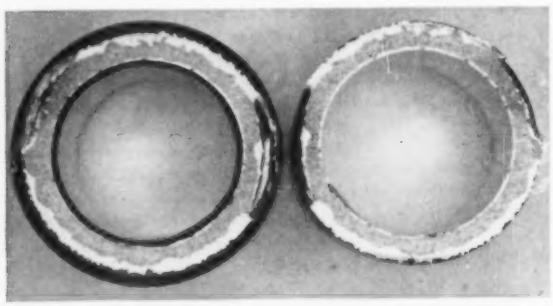


Fig. 1 Designs of heavy-wall tube joints investigated

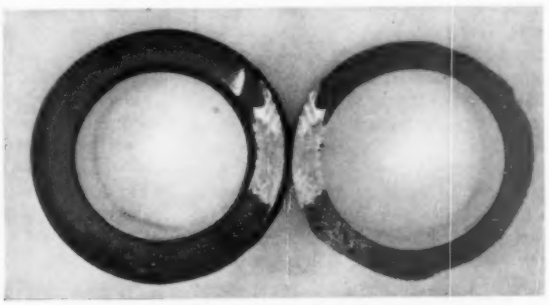
to have failed after 162 and 455 hr. The third specimen was thermally cycled by placing it in a 700° F furnace for 30 min, removing and allowing it to cool, and repeating the procedure twice. After this treatment the specimen appeared unchanged, but about 1¼ hr later it broke apart spontaneously. The behavior of these heat-treated weldments demonstrates the necessity for complete expulsion of fusion alloy from the joint and the necessity of avoiding diffusion-promoting thermal conditions if this method of joining is to be used.

The welding of tubing was first investigated with the simplest geometry—sections of 1$^{3}/_{16}$ in. OD x $^{1}/_{4}$ in. wall tubing. Thirty-three welds were made with a 500-kva machine which allowed wide variation of welding parameters coupled with close control. Two specimens were tested in tension as welded; failure occurred at 10,000- and 16,000-lb load. The other specimens were sectioned and examined metallographically to select the optimum welding conditions for this specimen geometry, after which the same conditions were used to prepare eleven duplicate weldments for thermal cycling and corrosion tests. Four specimens were subjected to thermal cycling of more than 100 cycles between 300 and 500° F, without visible damage. Two of the cycled specimens and seven which had not been cycled were corrosion tested in 680° F water for periods of 1182 to 1299 hr. They were then broken apart for examination. Five specimens suffered complete and extensive penetration of the wall, and three showed about 50% penetration from the inside only (the welding was controlled to favor the outer region, since corrosion resistance was not required inside the tube). The remaining specimen was attacked only at a few small, isolated spots on the inside surface (Fig. 3). The reproducibility of results was thus quite poor despite careful control of welding variables.

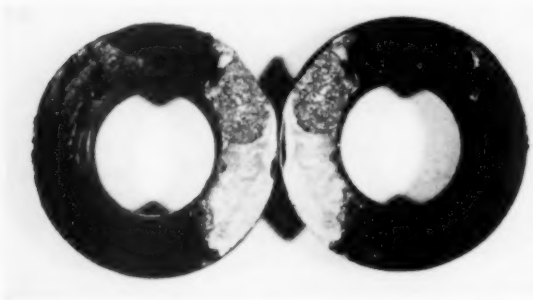
A set of eleven specimens was next prepared with a modified geometry as shown in Fig. 1*a*. The machine settings used during welding were the same as for the preceding set. All of these were judged to be unacceptably weak. This is in accord with the poor performance of flanged brazements dis-



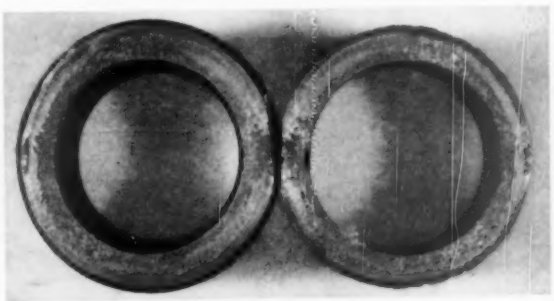
A. Filler metal, Ni – 20Pd – 10Si; exposure, 1475 hr. Spec. 7-3



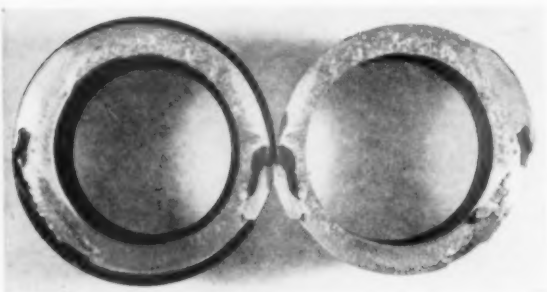
b. Filler metal, Ni – 30Ge – 13Cr; exposure, 1475 hr. Spec. 14-4



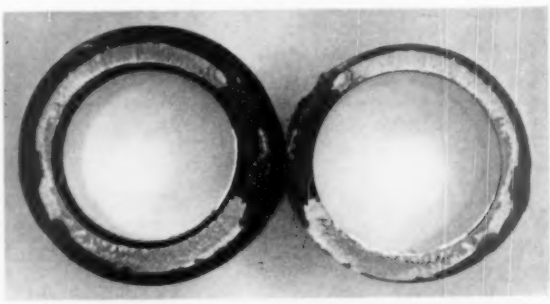
c. Filler metal, Cu – 20Pd – 3 In; exposure 1390 hr. Spec. 31-1



d. Filler metal, Zr – 2.5Be; exposure, 1356 hr. Spec. 34F-4



e. Filler metal, Cu – 18.5Pd – 4In; exposure, 1356 hr. Spec. 50-2



f. Filler metal, Cu – 18.5Pd – 4.5In; exposure, 1475 hr. Spec. 50-5

Fig. 2 Fracture surfaces of Zircaloy-to-stainless-steel brazements broken apart after corrosion tests in 680° F water. White surfaces are metal which remained sound. X 1

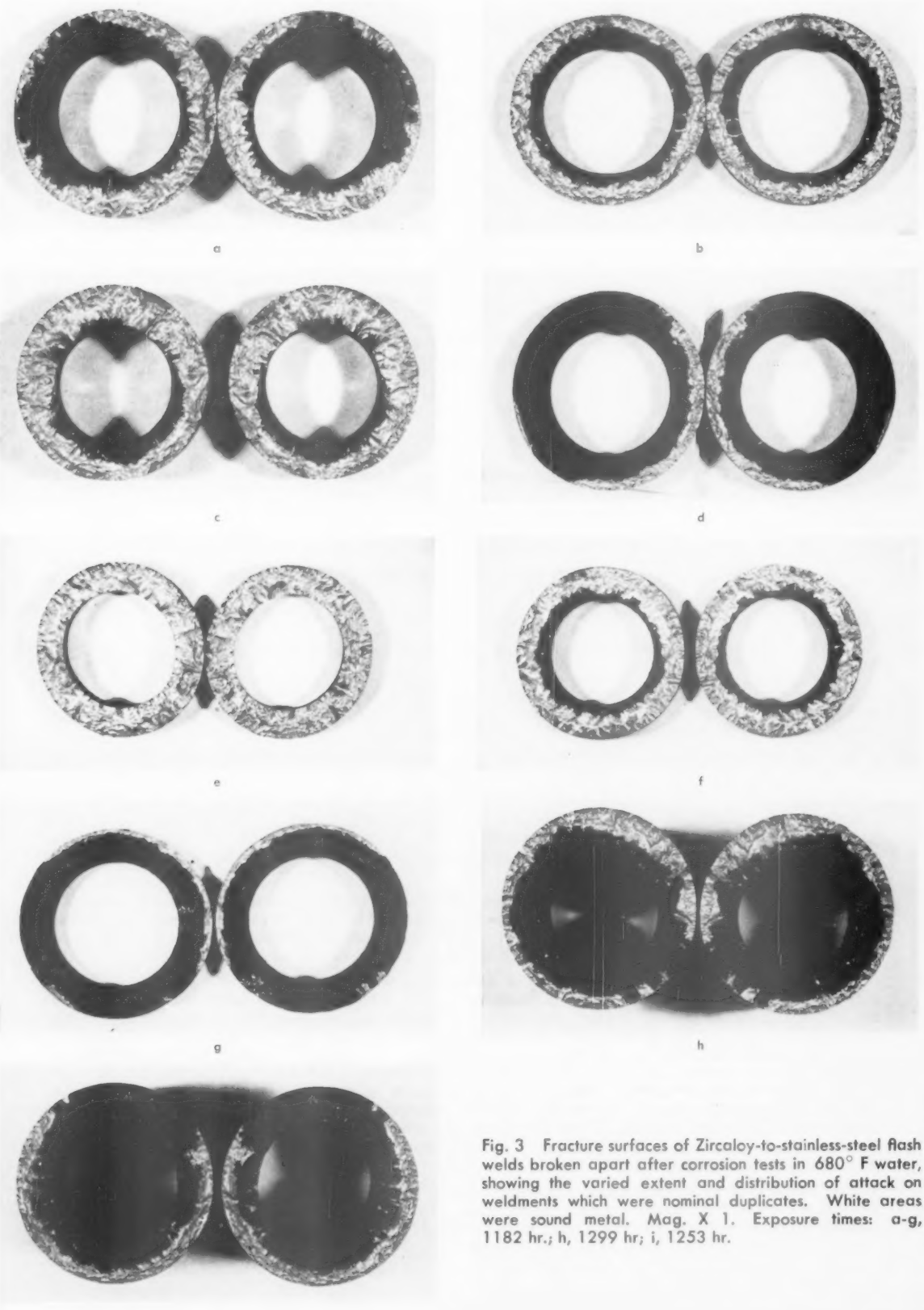


Fig. 3 Fracture surfaces of Zircaloy-to-stainless-steel flash welds broken apart after corrosion tests in 680° F water, showing the varied extent and distribution of attack on weldments which were nominal duplicates. White areas were sound metal. Mag. X 1. Exposure times: a-g, 1182 hr.; h, 1299 hr; i, 1253 hr.

cussed previously, and is probably due in part, at least, to the same cause, i.e., exceptionally unfavorable thermal stresses. Presence of the flange may also have affected the thermal gradients during the welding cycle sufficiently to increase the amount of highly alloyed material present in the completed joint.

Conclusion

The occasionally good results that were obtained with both flash-butt welding and brazing of Zircaloy to stainless steel, even with unfavorable joint geometry, indicate that either method might be useful for some applications. However, the quality of joint obtained will depend on the thermal stresses which the particular joint design entails. Brazing is therefore to be preferred, since this method permits greater flexibility of design. The brazing alloy prepared by adding approximately 4 wt % beryllium to Zircaloy-2 is judged to be the best of those which were investigated. Whether there is a toxicity hazard in the use of this alloy has not been determined, but suitable precautions should be taken on the assumption that there is such danger until the contrary has been proven.

Acknowledgment

The work reported by the authors was performed for Bettis plant which is operated by the Westinghouse Electric Corp. for the Atomic Energy Commission, and permission to publish this paper is acknowledged with gratitude. The helpful participation in this work of L. B. Prus, B. Schaaf and others of Bettis plant deserves recognition. Special thanks are also due R. Noland of the Argonne Laboratory, and R. Peachey of Sciaky Brothers, Inc., who performed the flash-welding experiments reported.

Reference

1. McAndrew, J. B., Schwartzbart, H., and Necheles, R., "Corrosion Resistance of Zircaloy-2 Brazements in High-Temperature Water," THE WELDING JOURNAL, 36 (6), Research Suppl., 287–290 (1957).

AN INVITATION TO AUTHORS

—to participate in the American Welding Society's

1959 NATIONAL FALL MEETING

Detroit, Mich.—Sept. 28–Oct. 1, 1959

Gentlemen:

The 1959 National Fall Meeting of the American Welding Society will be held in Detroit on Sept. 28–Oct. 1, 1959.

Twice each year our Society offers opportunities to Authors for bringing their outstanding work, development and research to the attention of our Membership and the welding and metals industry, by having previously unpresented and unpublished papers presented at its national meetings.

The Society's Technical Papers Committee will be happy to receive your application for entry in the 1959 National Fall Meeting activity. All applications, abstracts and manuscripts will be screened by the Committee, and Authors will be notified sometime in April 1959 regarding acceptance.

Each abstract should be sufficiently descriptive to give the Committee a clear idea of the content of the proposed paper. In any case, it should contain not less than 500—but not more than 1000—words. Also, in order to place the Committee in the best possible position to evaluate these papers, it is suggested that each abstract be accompanied by a complete manuscript.

The Committee reserves the right to consider all applications on the basis of acceptance for placing on the 1959 National Fall Meeting Program, or consideration for placing on the 41st Annual Meeting Program in April 1960, the next national meeting of the Society. Papers may be considered for publication in The Welding Journal regardless of acceptance for presentation at either Meeting.

Papers which deal with the latest developments in the following subjects are deemed to be of particular interest in Detroit: (1) welding as applied to automotive manufacturing operations; (2) resistance welding; (3) fabrication of "honeycomb" structures; (4) fabrication and maintenance of equipment used for radioactive applications; (5) pressure vessels and storage tanks; (6) equipment and pipe lines used in petroleum industry; (7) machinery design and fabrication; (8) structures; (9) automation as applied to resistance welding, inert-gas-shielded arc welding and other welding processes; (10) surfacing; (11) maintenance; (12) welding of castings and composite structures; (13) welding of dissimilar alloys or alloy systems; (14) welding of aluminum, magnesium, zirconium, titanium, Inconel and like metals; (15) brazing; (16) soft soldering; (17) welding of plastics; and (18) practical applications or "how-to-do" topics. However, any papers dealing with the educational and informative categories of welding production, engineering, research and metallurgy are welcomed as long as the subject falls within the field of our Society's activities.

Authors' Application Forms were mailed a few weeks ago to all members of our Society; additional copies may be obtained by writing directly to AWS headquarters. To assure consideration for the 1959 National Fall Meeting Program, abstracts must reach AWS not later than Jan. 15, 1959.

Sincerely,
Fred L. Plummer
National Secretary

FURTHER EVALUATION OF NI-CR-B AND AU-18NI BRAZING ALLOYS

Author discusses the tensile and impact properties of AISI 347 and of AISI 410 butt joints brazed with a Ni-Cr-B alloy and with the Au-18Ni alloy

BY WINSTON H. CHANG

ABSTRACT. The tensile and impact properties of AISI 347 and of AISI 410 butt joints brazed with a Ni-Cr-B alloy and with the Au-18Ni alloy are evaluated. Data are presented to show the changes of these properties as affected by temperature and/or joint clearance between room temperature and 1200° F. These changes, in turn, are discussed from a consideration of characteristics of the brazing alloys as well as the base metals.

In addition, some data are obtained on the 1500° F oxidation resistance of the brazed joints.

Introduction

In a previous paper,[1] the basic characteristics of five heat-resisting brazing alloys were described on the basis of room-temperature tensile test and microscopic examination. To assess the usefulness of these alloys for elevated-temperature applications, a Ni-Cr-B alloy and the Au-18Ni alloy were selected for brazing joints of AISI 410 and of AISI 347 stainless steels. These joints were subjected to tensile, impact and oxidation tests over a range of temperatures.

The compositions of the brazing alloys are listed in Table 1 from which the basis for choosing these two alloys is apparent. The Ni-Cr-B alloy typifies the multi-phase Ni-Cr-base alloys in that the mechanical properties of the brazed joints deteriorate with increasing joint clearance due to the appearance of brittle phases. Gold-18Nickel, on the other hand, is a solid-solution type alloy of which the basic structure, and hence the mechanical properties, do not vary appreciably with joint clearance.

Winston H. Chang is associated with Alloy Development, Flight Propulsion Laboratory, Aircraft Gas Turbine Division, General Electric Co., Evendale, Ohio.

When this paper was written, the author included information and expressed opinions believed to be correct and reliable. Because of the constant advance of technical knowledge, the widely different conditions of possible specific application, and the possibility of misapplication, any application of the contents of this paper must be at the sole discretion and responsibility of the user.

Experimental Procedure

Brazing

All specimens were of the butt-joint design. Details of the design and brazing procedure have been described previously.[1] In the present case, the joints brazed with Gold-18Nickel had a clearance of either "zero" or 0.004 in., whereas those brazed with the Ni-Cr-B alloy had a clearance of "zero." The brazing cycles were 2200° F/30 min and 2000° F/10 min for, respectively, the Ni-Cr-B alloy and Gold-18Nickel.

Table 1—Description of Brazing Alloys

Alloy	*Composition*	*Approximate liquidus, ° F*
Ni-Cr-B	15Cr, 4Si, 3.5B, 1C, 4Fe, bal. Ni	1925
Au-18Ni	18Ni, 82Au	1742

Post-Brazing Heat Treatment

Since the brazing temperatures were above the A_1 temperature of AISI 410, specimens made of this material were hardened from the as-received R_B60

Table 2—Tensile Properties of AISI 347 Joints Brazed with Ni-Cr-B Alloy

Brazing cycle: 30 min at 2200° F
Joint clearance: "Zero"
Condition: As brazed

Test temperature, ° F	*Sample**	*Tensile strength, psi* Indiv.	Avg.	*Elongation, % in 1 in.* Indiv.	Avg.	*Reduction in area, %*	*Location of failure*
Room temperature	Base metal	85,100	84,800	57	56.5	57	
		84,500		56		57	
	Joint	87,740	86,910	22	34.0	24	J(Joint)
		87,000		42		38	J
		86,000		38		43	J
	Base metal	66,200	65,850	44	44.0	64	
		65,500		44		65	
500	Joint	66,000	65,600	38	37.3	59	B(Base)
		65,700		37		52	B
		65,200		37		55	B
	Base metal	66,300	66,100	43	43.0	60	
		65,900		43		60	
800	Joint	66,700	64,500	36	31.7	56	B
		66,400		35		53	B
		60,300		24		33	J
	Base metal	62,000	61,800	42	40.5	58	
		61,600		39		56	
1000	Joint	62,400	62,000	44	38.3	55	B
		62,300		30		20	J
		61,300		41		56	B
	Base metal	58,000	57,000	42	38.0	58	
		56,000		34		33	
1200	Joint	55,600	49,050	33	23.5	28	J
		42,500		14		20	J

* Base material samples were subjected to same brazing cycle.

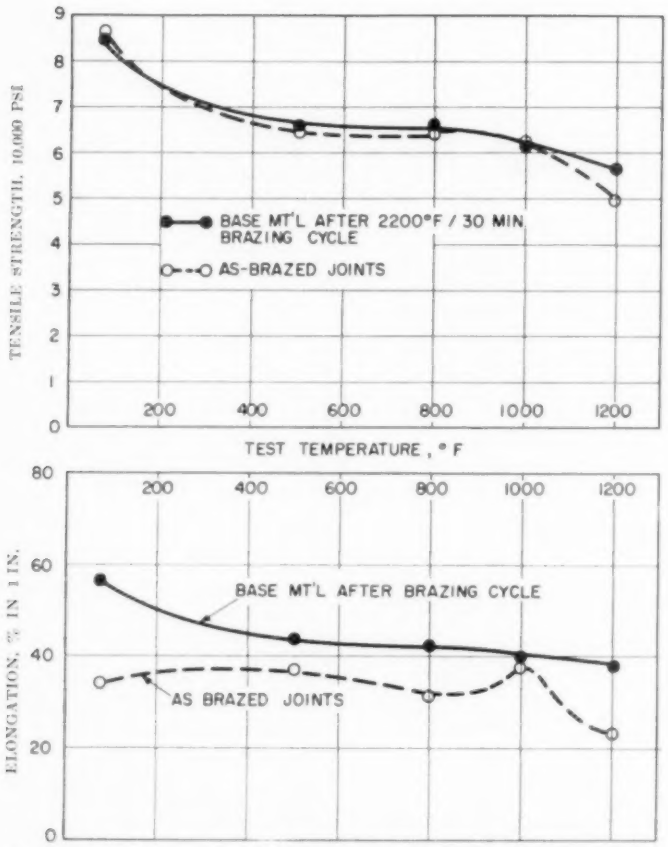

TENSILE STRENGTH, 10,000 PSI
BASE MT'L AFTER 2200°F / 30 MIN. BRAZING CYCLE
AS-BRAZED JOINTS
TEST TEMPERATURE, °F
ELONGATION, % IN 1 IN.
BASE MT'L AFTER BRAZING CYCLE
AS BRAZED JOINTS

Fig. 1 Tensile properties of AISI 347 joints brazed with Ni-Cr-B alloy

to R_c40 as a result of brazing. Some of the AISI 410 tensile specimens were tested in the as-brazed condition. The majority, however, were tempered at 1200° F for 3 hr after brazing. This tempering restored the hardness and tensile properties of the brazed specimens to approximately those of the as-received base metal.

Testing

Tensile Test. Standard 0.250-in. tensile bars were machined from the brazed specimens. The test was conducted at room temperature, 500, 800, 1000 and 1200° F.

Oxidation Test. To evaluate the oxidation resistance of the brazed joint, as-brazed AISI 347 specimens were machined into 0.250-in. tensile bars. The latter were placed in a muffle furnace at 1500° F for 1, 2, 4 and 8 weeks. During the exposure, air was circulated over the tensile bars at a rate of 10 ft^3/hr. After the exposure, the oxidation resistance of the joints was evaluated by microscopic examination for depth of oxidation and by room-temperature test for loss of strength.

Impact Test. Standard Charpy V-notch specimens with the root of the notch contained in the brazed joint were tested both at room temperature and at 1200° F.

Results and Discussion

Tensile-Test Results

AISI 347 Joints. The tensile properties of AISI 347 specimens brazed with the Ni-Cr-B alloy and Au-18Ni are given in Tables 2 and 3 and are also shown in Figs. 1 and 2. Since all the specimens brazed with the Ni-Cr-B alloy had "zero" clearance, they were free of brittle phases, as shown in Fig. 3*A*. Whether the specimens failed in the base metal or in the joint appeared to be purely incidental, except at temperatures above 1000° F. At the latter temperatures, the tensile fracture always occurred in the joint. It is apparent from Fig. 1 that regardless of the location of failure, the brazed joint was practically as strong as the base material over the entire range of testing temperatures (75 to 1200° F). Furthermore, the fracture did not occur until a substantial amount of elongation had taken place. These results characterize a high-melting, solid-solution type brazed joint which maintains a high level of strength and ductility over a wide range of temperatures. In this respect, the Ni-Cr-B alloy, when used at small clearances, is superior to Au-18Ni which melts at a lower temperature. Figure 2 shows that the AISI 347 joint brazed with Au-18Ni exhibited equal or greater strength than the base material up to about 600 or 800° F, depending upon whether the clearance was "zero" or 0.004 in. Above these temperatures, the brazed-joint strength deteriorated with temperature at a faster rate than did the strength of the stainless steel. As a consequence, fracture of the tensile bars always occurred in the joint at stress levels somewhat below the corresponding tensile strength of the base material. It will also be noted that at the elevated temperatures, the 0.004-in. joints showed consistently higher strength than the "zero" joints. Based on the fact that molten Au-18Ni dissolves Fe-Cr-Ni base metals, the superiority of the 0.004-in. joints apparently was related to the greater extent of alloying of Au-18Ni by the Fe and Cr from the base material, resulting in greater strengthening of the brazed joint.

In comparing the high-temperature performance of Au-18Ni with the Ni-Cr-B alloy, the effect of joint clearance should be taken into consideration. As will be verified later by some of the impact-test results, the multi-phased structure of the Ni-Cr-B alloy remained brittle at 1200° F. If the Ni-Cr-B alloy is compared with Au-18Ni at the same joint clearance of 0.002 in. or over, the joints brazed with Au-18Ni, despite its lower melting temperature, will in all probability be superior in tensile properties over the temperature range of from 75 to 1200° F. On the other hand, the joints brazed with the Ni-Cr-B alloy will definitely show increasingly better performance at temperatures above 1200° F.

AISI 410 Joints. The tensile properties of AISI 410 brazed with Ni-Cr-B alloy are tabulated in Table 4 and plotted in Fig. 4. Before discussing the results, one important aspect of the base metal-brazing alloy reactions should be pointed out. It will be recalled again that all specimens brazed with Ni-Cr-B had 'zero" clearance. The specimen preparation, amount of brazing alloy and brazing cycle were such that when using N-155, AISI 347 and AISI 405 as base metals, sufficient diffusion took place between the joint and the base metal so that no brittle phases appeared in the resulting joint.[1] This, however, apparently was not true in the case of AISI 410. Using exactly the same brazing procedure, some secondary phases invariably remained in the "zero" joints

Table 3—Tensile Properties of AISI 347 Joints Brazed with Au-18Ni Alloy

Brazing cycle: 10 min at 2000° F
Condition: As brazed

Test temperature, ° F	Sample*	Joint clearance, in.	Tensile strength, psi — Indiv.	Tensile strength, psi — Avg.	Elongation, % in 1 in. — Indiv.	Elongation, % in 1 in. — Avg.	Reduction in area, %	Location of failure
Room temperature	Base metal		87,000	86,800	53	54	57	
			86,600		54		57	
	Joint	"zero"	88,000	88,000	49	50	63	B(Base)
			88,000		50		63	B
		0.004	86,000	86,000	52	53	58	B
			86,000		54		59	B
500	Base metal		66,300	66,050	40	41	61	
			65,800		41		61	
	Joint	"zero"	66,000	64,900	41	41	61	B
			65,800		41		61	
			63,000		40		63	B
	Joint	0.004	66,000	65,900	38	37	59	B
			65,700		37		52	B
			65,200		37		55	B
800	Base metal		64,900	64,500	40	41	60	
			64,000		41		60	
		"zero"	58,200	57,700	18	17	26	J(Joint)
			57,100		16		18	J
	Joint	0.004	64,100	63,300	35	28	59	B
			63,700		25		20	J
			62,000		23		19	J
1000	Base metal		59,900	59,900	39	39	57	
			59,800		39		54	
	Joint	"zero"	58,500	55,150	18	12	26	J
			51,800		11		18	J
		0.004	56,600	56,200	17	16	19	J
			56,500		17		17	J
			55,400		15		18	J
1200	Base metal		51,800	51,700	46	45	90	
			51,500		44		61	
			40,900	39,000	8	6	13	J
			38,500		57		7	J
			37,500		4		7	J
	Joint	0.004	46,400	46,000	14	13	19	J
			46,400		12		15	J
			45,100		12		16	J

* Base material samples were subjected to the brazing cycle.

Table 4—Tensile Properties of AISI 410 Joints Brazed with Ni-Cr-B Alloy

Brazing cycle: 30 min at 2200° F
Joint Clearance "zero"

Test temperature, ° F	Sample	Condition*	Tensile strength, psi — Indiv.	Tensile strength, psi — Avg.	Elongation, % in 1 in. — Indiv.	Elongation, % in 1 in. — Avg.	Reduction in area, %	Location of failure
Room temperature	Base metal	B.C.	197,000	196,000	14	14.5	38	
			195,000		15		40	
		H.T.	106,300	106,000	25	25.0	65	
			105,800		25		66	
	Joint	A.B.	110,000	107,300	0	0	0	J(Joint)
			110,000		0		0	J
			104,500		0		0	J
		H.T.	102,100	100,000	3	2.7	3	J
			99,100		3		6	J
			98,900		2		3	J
500	Base metal	B.C.	201,000	200,600	12	12.0	26	
			200,200		12		26	
		H.T.	90,400	90,250	21	21.0	71	
			90,100		21		70	
	Joint	A.B.	110,500	107,500	0	0	0	J
			104,500		0		0	J
		H.T.	87,600	85,200	3	2.7	2	J
			84,800		3		2	J
			83,100		2		2	J
800	Base metal	H.T.	80,900	80,750	19	19.0	62	
			80,600		19		61	
	Joint	H.T.	83,000	81,500	6	9.0	6	J
			81,600		18		52	B(Base)
			79,800		3		4	
1000	Base metal	B.C.	142,000		13		43	
			139,000		13		43	
		H.T.	62,000	62,000	28	28.0	84	
	Joint	A.B.	106,200	104,000	1	1.0	0	J
			104,000		1		0	J
			102,000		1		0	J
	Joint	H.T.	62,100	61,600	25	26.3	82	B
			62,100		27		80	B
			60,600		28		86	B
1200	Base metal	B.C.	40,300		32		91	
			38,600		48		90	
		H.T.	36,000	36,000	38	38.0	94	
	Joint	A.B.	37,800	37,100	36	38.3	92	B
			36,800		39		92	B
			36,800		40		87	B
	Joint	H.T.	36,600	35,400	41	39.0	94	B
			35,800		38		92	B
			33,700		38		94	B

* B.C.: Base metal subjected to brazing cycle. H.T.: Brazed joint or base metal tempered for 3 hr at 1200° F after the brazing cycle. A.B.: As brazed.

brazed with the Ni-Cr-B alloy. A typical example of the microstructure is shown in Fig. 3A. Comparing the latter with Fig. 3A, it is seen that the same brazing cycle had resulted in a larger final joint clearance in the AISI 410 specimens than in the AISI 347 specimens. The persistence of the secondary phases in the AISI 410 joints may thus be attributed to the dissolution of the base material, which proceeded at a rate greater than the rate with which the alloying elements constituting the secondary phases diffused into the base metal.

Returning to Fig. 4, it is seen that in the as-brazed condition, AISI 410, which is a hardenable stainless steel, possessed a very high tensile strength between room temperature and 1000° F. Within this range, the joints brazed with the Ni-Cr-B alloy sustained stresses over 100,000 psi although the failure was always in the joint accompanied by nil ductility.

At temperatures over 1000° F, which approaches the A_1 temperature of AISI 410, the strength of the base metal apparently decreased more rapidly than the strength of the brazing alloy which undergoes no transformation until its solidus. As a result, fracture took place in the base metal, accompanied by a sharp rise in elongation.

The effect of tempering the AISI 410 joints after brazing was to lower the strength and raise the ductility of the base metal. Figure 4 shows that in the tempered condition, the joint and base metal had nearly equal strength over the entire range of testing temperatures. The joint ductility, however, was very low at temperatures below 800° F, which was to be expected in view of the presence of the secondary phases as noted above. The fracture occurred in the joint at temperatures below 1000° F and in the base material at higher temperatures.

The tensile-test results of AISI 410 brazed with Au-18Ni at either "zero" or 0.004-in. clearance are given in Table 5 and Fig. 6. Note the exceedingly high strength of the as-brazed 0.004-in. specimens, all of which failed in the joint. At temperatures up to 600° F, the joint was practically as strong as the base metal, having a tensile strength of 195,000 psi and an elongation of 8% in 1 in. Above 600° F, the joint strength gradually fell below the strength of the base metal but still remained superior to the strength of as-brazed AISI 410 brazed with the Ni-Cr-B alloy, until 1000° F.

As with the AISI 347 joints, the

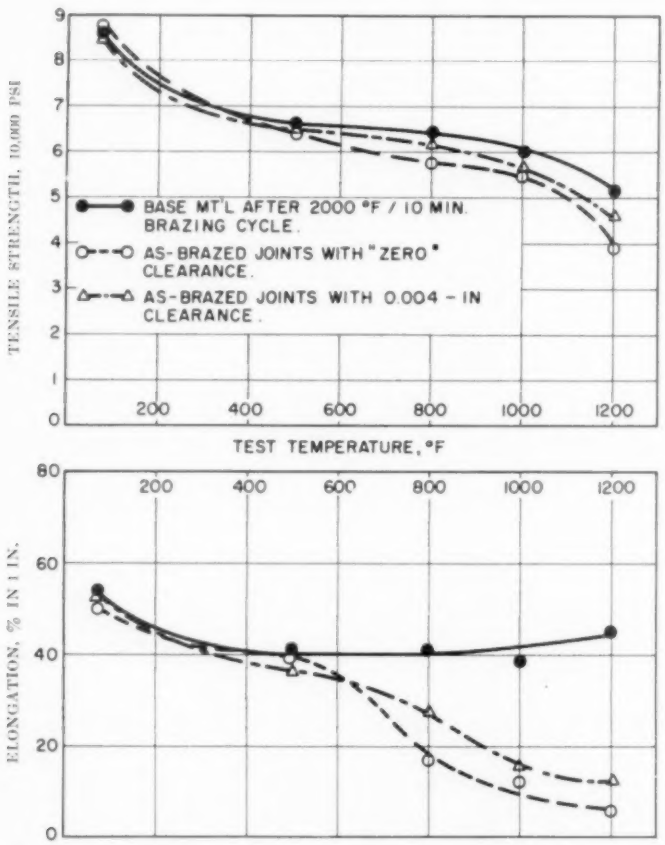
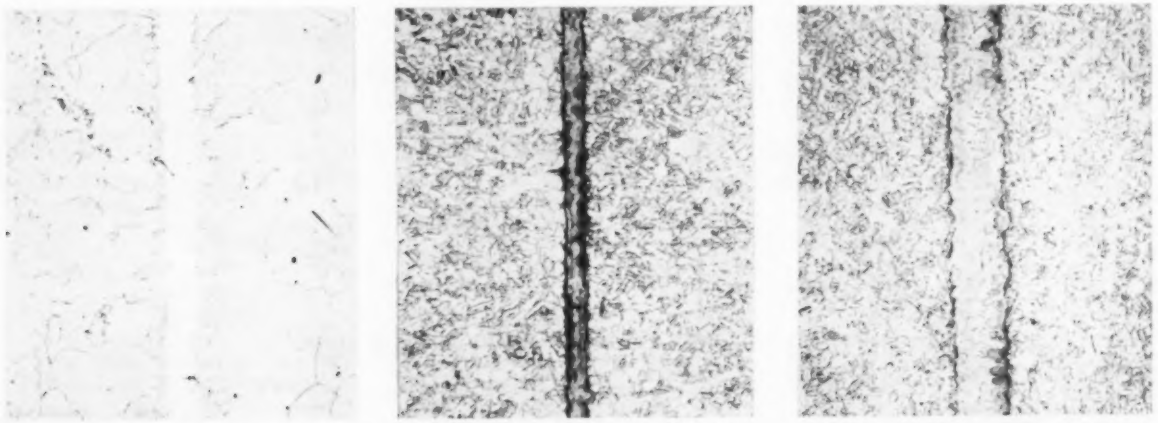

TENSILE STRENGTH, 10,000 PSI
BASE MT'L AFTER 2000 °F / 10 MIN. BRAZING CYCLE.
AS-BRAZED JOINTS WITH "ZERO" CLEARANCE.
AS-BRAZED JOINTS WITH 0.004 - IN CLEARANCE.
TEST TEMPERATURE, °F
ELONGATION, % IN 1 IN.

Fig. 2 Tensile properties of AISI 347 joints brazed with AU-18 Ni alloy



A. Brazed with Ni-Cr-B alloy. "Zero" clearance

B. Brazed with Au-18Ni. "Zero" clearance

C. Brazed with Au-18Ni. 0.004-in. clearance

Fig. 3 Microstructures of brazed AISI 347 joints. X 100. (Reduced by 30% upon reproduction)

Table 5—Tensile Properties of AISI 410 Joints Brazed with Au-18Ni Alloy

Brazing cycle: 10 min at 2000° F

Test temperature, ° F	Sample	Clearance, in.	Condition*	Tensile strength, psi		Elongation, % in 1 in.		Reduction in area, %	Location of failure
				Indiv.	Avg.	Indiv.	Avg.		
75	Base metal		B.C.	191,000	190,500	15	15.5	50	
				190,000		16		50	
		"zero"	H.T.	104,500	103,800	26	26.5	70	
				103,000		27		69	
			H.T.	107,000	106,000	19	18.0	61	B
				105,000		17		53	B
	Joint	0.004	A.B.	195,700	194,700	7	7.7	10	J
				195,500		8		12	J
				193,000		8		16	J
			H.T.	108,000	107,200	27	26.3	71	B
				107,500		26		71	B
				106,000		26		71	B
500	Base metal		B.C.	195,500	194,800	12	12.0	28	
				194,000		12		33	
			H.T.	89,300	89,150	19	19.0	72	
				89,000		19		72	
	Joint	0.004	A.B.	198,000	196,300	6	5.7	8	J
				196,000		6		6	J
				194,800		5		8	J
			H.T.	92,200	90,800	20	20.3	71	B
				90,200		20		73	B
				90,000		21		70	B
800	Base metal		H.T.	80,500	80,000	19	19.0	70	
				79,500		19		68	
	Joint	"zero"	H.T.	83,000	82,850	9		29	B
				82,500		13		39	B
		0.004	H.T.	81,700	80,800	21	20.0	68	B
				81,200		20		66	B
				79,600		20		74	B
1000	Base metal		B.C.	147,000	143,000	15	15.5	47	
				139,200		16		50	
			H.T.	63,500	61,500	25	25.0	82	
				59,500		25		83	
	Joint	"zero"	H.T.	61,400	60,700	4	11.0	18	J
				60,000		18		58	B
		0.004	A.B.	106,700	103,100	2	2	0	J
				102,500		1		0	J
				100,000		2		0	J
				61,900	61,700	29	26.3	84	B
				61,900		21		28	J
				61,300		29		84	B
1200	Base metal		B.C.	38,600	35,850	44	36.0	92	
				33,100		28		92	
			H.T.	37,200	37,000	44	40.0	91	
				36,800					
	Joint	"zero"	H.T.	34,600	33,250	8	11.0	22	J
				31,900		14		25	J
		0.004	A.B.	40,800	38,400	9	10.0	20	J
				38,000		10		18	J
				36,400		11		18	J
			H.T.	37,700	36,100	22	14.7	95	B
				35,600		13		29	J
				35,000		9		27	J

* B.C.: Base metal subjected to brazing cycle only. H.T.: Brazed joint or base metal tempered for 3 hr at 1200° F after brazing cycle. A.B.: As brazed.

Table 6—Charpy V-Notch Impact Results of Brazed AISI 347 Joints

Filler metal	Joint clearance, in.	Test temperature, ° F	Impact values, ft-lb	
			Indiv.	Avg.
Base metal after the 2220° F/30 min brazing cycle		75	>231	222
			>221	
			>213	
		1200	175	157
			154	
			152	
			146	
Ni-Cr-B alloy	"Zero"	75	39	37
			38	
			36	
			36	
		1200	60	52
			53	
			48	
			46	
Base metal after the 2000° F/10 min brazing cycle		75	>240	220
			>225	
			>196	
		1200	<154	150
			<152	
			<144	
Au-18Ni alloy	"Zero"	75	55	49
			51	
			50	
			40	
		1200	81	62
			68	
			59	
			50	
	0.004	75	35	32
			34	
			30	
			30	
		1200	47	46
			46	
			45	
			45	

hot strength of AISI 410 brazed with Au-18Ni was slightly higher at a clearance of 0.004 in. than at a "zero" clearance. Regardless of clearance, these joints were at least as strong as the base material except at 1200° F where the base material was stronger. Figure 7 shows considerably higher values of elongation for the 0.004-in. joints. By referring to Table 5, however, it will be observed that up to 1000° F, most of the specimens, regardless of clearance, failed in the base metal. The lower elongation of the "zero" specimens was then a reflection of the inferiority of the base metal (obviously due to improper tempering) rather than of the Au-18Ni joint.

Impact-Test Results

This test was conducted at room temperature and at 1200° F on V-notch Charpy bars prepared individually from AISI 347 and AISI 410. Each of the base materials was brazed under the following three conditions.

(*a*) Brazed with Ni-Cr-B alloy at "zero" clearance.
(*b*) Brazed with Au-18Ni at "zero" clearance.
(*c*) Brazed with Au-18Ni at 0.004-in. clearance.

The impact-test results for the AISI 347 joints are shown in Table 6 and Fig. 7. All three groups exhibited satisfactory impact values at room temperature and higher values at 1200° F, as is to be expected from joint microstructures which neither contain embrittling phases nor undergo

aging during the test. In general, the impact results were well correlated with the tensile-test results previously shown in Figs. 1 and 2, except for the effect of joint clearance on the specimens brazed with Au-18Ni. Whereas the 0.004-in. joints had higher hot tensile strength than the "zero" joints, the latter possessed higher impact values than the joints with the larger clearance. Although impact results are known to show a scatter, particularly for brazed joints, present data given in Table 6 indicate that the difference was consistent and, in all likelihood, real. Apparently, these results must be interpreted in terms of the toughness of the base metal *relative* to that of the brazing alloy in the joint. In an impact test of the present nature, the deformation of the joint is closely influenced by the surrounding base metal. Although the striking edge of the test machine is directed onto the brazed joint, some of the impact energy is absorbed by the base material, more so the thinner the joint. The net test result thus depends on the volume as well as the toughness of the joint relative to those of the nearby base material. If the base metal is tougher than the brazing alloy in the joint, as is in the case of AISI 347 compared with Au-18Ni, then the impact values of the brazed specimen will decrease with increasing joint clearance. This follows since an increasing amount of the impact energy is now applied onto a greater volume of the brazing alloy which has a lower capacity for absorbing the impact. Furthermore, the interference from the base metal, which restrains the joint, was reduced at larger clearances.

On the other hand, if the base metal were brittle relative to the brazing alloy, the over-all impact values of the brazed specimen would be expected to improve with increasing joint thickness. As the volume of the brazing alloy increases with clearance, the influence of the base metal is gradually replaced by that of the tougher brazing alloy, resulting in greater amount of energy being absorbed. An example of this is to be found in the case of AISI 410 brazed with Au-18Ni. Present results for these specimens are given in Table 7 and Fig. 8. The relatively low toughness of AISI 410 is clearly indicated by the low impact values (Table 7) of the base metal after the brazing and tempering treatments. When brazed with Au-18Ni, it is seen that the

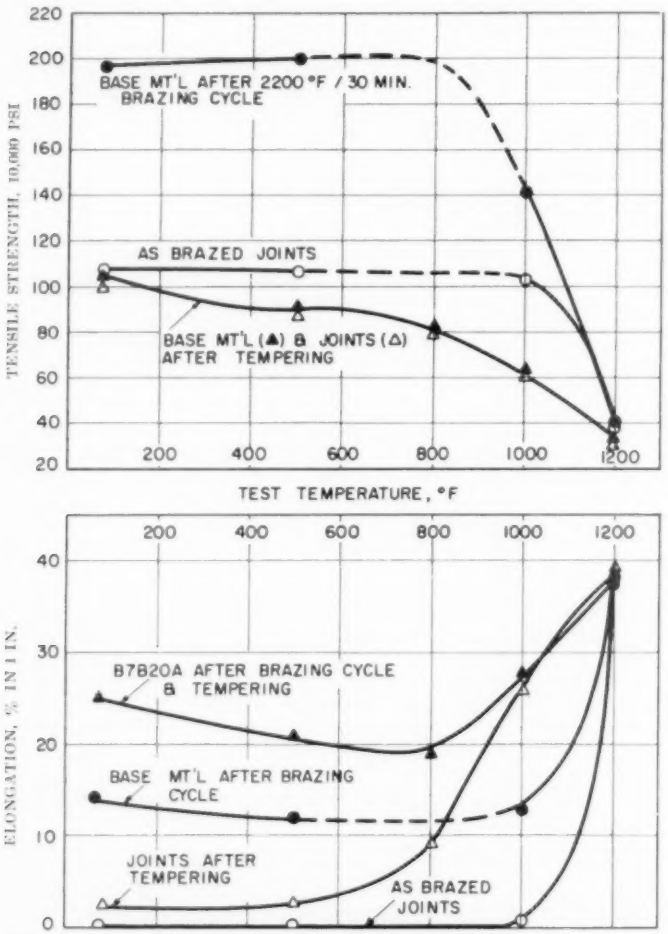


Fig. 4 Tensile properties of AISI 410 joints brazed with Ni-Cr-B alloy

A. Brazed with Ni-Cr-B alloy. "Zero" clearance

B. Brazed with Au-18Ni. "Zero" clearance

C. Brazed with Au-18Ni. 0.004 in. clearance

Fig. 5 Microstructures of brazed AISI 410 Joints. X 100. (Reduced by 30% upon reproduction)

Table 7—Charpy V-Notch Impact Results of Brazed and Tempered AISI 410 Joints

Filler metal	Joint clearance, in.	Test temperature, °F	Impact values, ft-lb Indiv.	Avg.
Base metal after 2200° F/30 min brazing cycle and 1200° F/3 hr tempering		75	89 85 81	85
		1200	79 76 72	76
Ni-Cr-B	"Zero"	75	2 1 1	1
		1200	7 3 3	4
Base metal after 2000° F/10 min brazing cycle and 1200° F/3 hr tempering		75	78 73 68	73
		1200	71 69 63	68
	"Zero"	75	10 8 8 5	8
Au-18Ni alloy	0.004	75	33 31 21	28
	"Zero"	1200	59 46 43 33	45
	0.004	1200	79 78 77	78

Table 8—Room-Temperature Tensile-Test Results of Brazed AISI 347 Joints after Oxidation

Brazing alloy	Oxidation time, weeks	Tensile strength, psi	Elongation, % in 1 in.	Reduction in area, %	Location of failure
Ni-Cr-B alloy ("zero" clearance)	0	86,910	34	35	J
	1	84,500	30	32	J
	2	85,000	30	33	J
	4	84,500	37	34	J
	8	83,000	31	32	J
Au-18Ni (0.004-in. clearance)	0	88,000	50	63	B
	1	94,000	52	64	B
	2	91,500	57	56	B
	4	91,500	51	57	B
	8	90,900	39	31	B&J

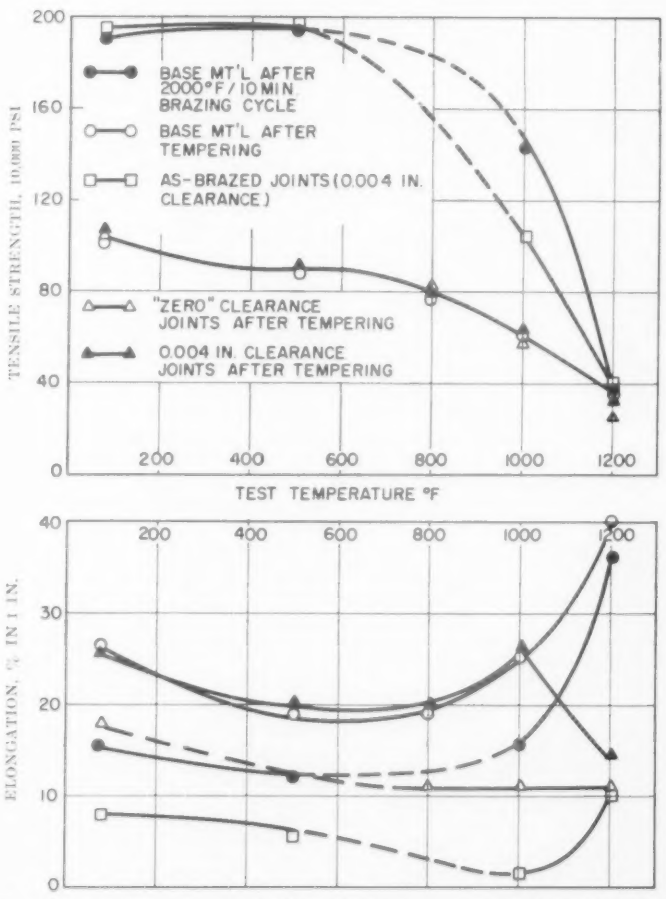


Fig. 6 Tensile properties of AISI 410 joints brazed with AU-18Ni alloy

0.004-in. joints had appreciably higher impact values than the "zero" joints. In fact, the influence of the brazing alloy was so predominant at the 0.004-in. clearance that, at 1200° F, the impact values of the joints (78 ft-lb) were actually higher than those of the base material alone (68 ft-lb).

The extremely low impact values of AISI 410 joints brazed with the Ni-Cr-B alloy are noteworthy. As indicated previously, these low values resulted from the presence of brittle phases due to insufficient diffusion of certain alloying elements from the joint into the base metal. The embrittling effects of these phases were thus better demonstrated in the impact test than in the tensile test. It will also be noted that the toughness of these joints did not improve significantly at 1200° F.

Oxidation-Test Results

As described previously, the oxidation test consisted of heating brazed AISI 347 tensile bars in an air-circulating furnace at 1500° F for 1, 2, 4 or 8 weeks. Both the exposure and subsequent test and examination were intended only to be indicative of the oxidation resistance of the brazed joints.

After the longer periods of exposure, appreciable scaling formed on the base metal. Visual inspection indicated that less oxidation had taken place around the joint, particularly in the case of the joints brazed with the Ni-Cr-B alloy. This was substantiated by microscopic examinationa, and the excellent oxidation resistance of the Ni-Cr-B alloy is illustrated in the photomicrograph shown in Fig. 9*A*. On examining under higher magnification, it was found that some precipitation had occurred in the joint as shown in Fig. 9*B*. Apparently, this precipitation was caused by the heating but was not related to oxidation.

Figure 9*C* shows a photomicrograph of

an AISI 347 joint brazed with Au-18Ni and oxidized at 1500° F for four weeks.

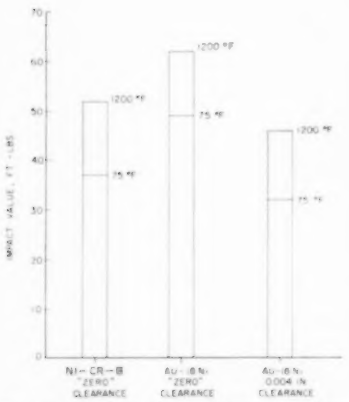


Fig. 7 Charpy V-notch impact values of brazed AISI 347 joints

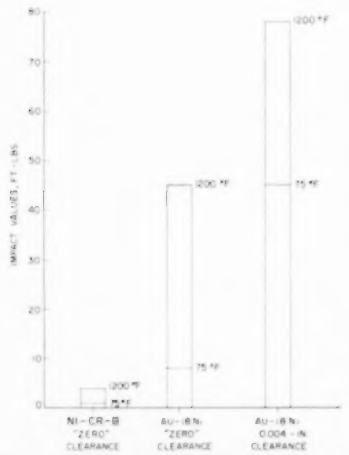


Fig. 8 Charpy V-notch impact values of brazed and tempered AISI 410 joints

The joint etched very dark after the exposure. This darkening resulted from interdiffusion between the joint and the base material rather than from oxidation effects.

That both the Ni-Cr-B alloy and Au-18Ni exhibited remarkable oxidation resistance may also be deduced from the room-temperature tensile-test results, given in Table 8, of the exposed bars. In general, the brazed joints retained satisfactory tensile properties even after two months' exposure. In the case of joints brazed with Au-18Ni, an increase in tensile strength over the as-brazed joints occurred through the strengthening of the base metal after being heated at 1500° F. Such a base-metal strengthening must also have taken place in the specimens brazed with the Ni-Cr-B alloy. The latter, however, all fractured in the joint and showed a general reduction in strength and ductility after the oxidation test. Apparently, this reduction in tensile properties resulted mainly from aging of the joint, as shown in Fig. 11*B*.

Conclusions

1. The tensile strength of butt joints of AISI 347 brazed with the Ni-Cr-B alloy at "zero" clearance is practically equal to the base-metal tensile strength within the temperature range of from 75 to 1200° F.

2. The tensile strength of AISI 347 joints brazed with Au-18Ni is equal to the base metal up to 600° F for the "zero" joints and up to 800° F for the 0.004-in. joints. Above these temperatures, the joints become weaker than the base metal, more so at "zero" than at 0.004-in. clearance. The better hot strength at the larger clearance is attributed to the strengthening of the Au-18Ni by the dissolution of the base metal.

3. Rate of dissolution of AISI 410 by the Ni-Cr-B alloy appears to be more rapid than the rate of diffusion of the brazing alloy into the base metal, resulting in brittle phases retained in "zero" joints. These joints possess strength equal to that of the base metal between 75 and 1200° F. Ductility, however, is very low when fracture occurs in the joint at temperatures below 800° F.

4. Untempered AISI 410 joints brazed with Au-18Ni at 0.004-in. clearance show strength over 190,000 psi at temperatures below 500° F. After tempering, the joints, regardless of clearance, exhibit tensile properties approximately equal to those of the base metal over the entire range of testing temperatures.

5. AISI 347 butt joints brazed with either the Ni-Cr-B alloy or Au-18Ni show excellent impact resistance which is higher at 1200° F than at room temperature. The joints brazed with Au-18Ni exhibit higher impact values at "zero" than at 0.004-in. clearance.

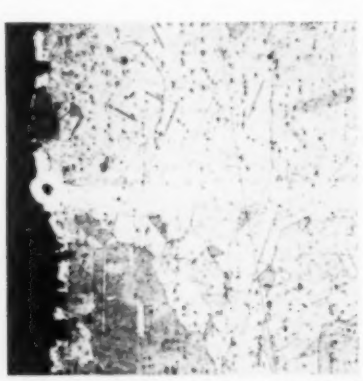
6. The AISI 410 joints brazed with Ni-Cr-B alloy at "zero" clearance show poor impact values because of the presence of brittle phases. The impact resistance of AISI 410 joints brazed with Au-18Ni is satisfactory at "zero" clearance and excellent at 0.004-in. clearance. The effects of clearance on the impact properties of the brazed joint are explained on the basis of toughness of the base metal relative to that of the brazed joint.

Acknowledgment

The assistance given by the late R. B. Sausville throughout this investigation is gratefully acknowledged.

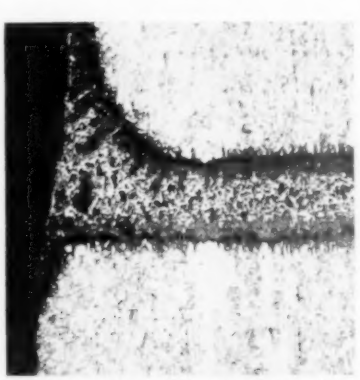
References

1. Chang, W. H., "Basic Characteristics of Some Heat-Resisting Brazing Filler Materials," The Welding Journal, 35(9), Research Suppl., 431-s (1956).



A. Brazed with Ni-Cr-B alloy and oxidized for 4 weeks. X 100

B. Same as (A), showing precipitation after oxidation. X 500



C. Brazed with Au-18N and oxidized for 4 weeks. X 100

Fig. 9 Microstructures of AISI joints after 1500° F oxidation. (Reduced by 30% upon reproduction)

EFFECTS OF PREHEATING, THERMAL STRESS RELIEF AND ELECTRODE TYPE ON NOTCH TOUGHNESS

Investigation undertaken to determine what comparative benefits in notch toughness of weldments may be realized through use of preheating for welding, as against thermal stress relief, or by changing from Type E6010 to Type E6016 electrode

BY L. J. McGEADY

INTRODUCTION: Preheating has been recognized and used very commonly to improve ease of fabrication of mild-steel weldments by helping to eliminate cracking in the weld metal and in the heat-affected area next to the weld. Commonly, this preheating is actually only a prewarming to bring plate temperatures up to about 100° F. This report deals with preheating to higher temperatures for the intended purpose of improving the performance in service of low-carbon steel weldments. Although such preheating might also conceivably serve to prevent fabrication difficulties in the same weldments, such is not any part of the purpose.

The ASME Boiler Code in Section VIII for Unfired Pressure Vessels makes thermal-stress-relief heat treatment mandatory for all welded pressure vessels of carbon steel in thickness greater than one and one-quarter inches. It is sometimes very difficult and extremely expensive to accomplish such heat treatment, particularly in cases of field erection or assembly where it may be practically impossible. This report deals with an investigation that was undertaken to determine what comparative benefits in notch toughness of weldments might be realized through use of preheating for welding, as against thermal stress relief, or change from cellulosic-coated E6010 electrode to low-hydrogen Type E6016 electrode. The work was performed for the Pressure Vessel Research Committee under suggested objectives and directions from a Subcommittee on Preheating and Postheating of its Fabrication Division.

Earlier work with E6010 electrode reported by DeGarmo[1] has indicated that preheating carbon-steel-plate weld specimens three-quarters inch thick to a temperature of 400° F confers properties comparable to those obtained by thermal stress relief after welding. Work on welded structural beams at Columbia University[2] has also shown benefits from preheating for welding, using E6011 and E6020 electrodes. In addition, the work on hatch-corners at California[3] showed that preheating improves weld performance in full-scale weldments using cellulosic-coated electrodes. In all these cases, the purpose of preheat was not to promote ease of fabrication but to improve service performance. Clear-cut cases of improvement in toughness by preheat of low-hydrogen weldments are not to be found in the literature.

With this as background it was thought desirable to investigate further along these lines. Such variables as effect of steels welded, electrode types such as low-hydrogen, thermal stress relieving and temperature of preheat have been included in this investigation for comparative study. This has been done using a specimen which offers combined outstanding advantages of small scale specimens such as the Kinzel type and advantages of very large specimens such as hatch corners. The specimen which has been developed (Figs. 1 and 2) is reproducible and large enough to simulate many of the conditions found in fabrication and use of commercial weldments. Probably the outstanding features of the specimen are (1) a full-thickness butt-joint weld, (2) a long weld and (3) sufficient mass of metal to reproduce thermal cycles which occur in commercial weldments.

The guiding subcommittee felt that a notch 0.080 in. deep, 6 in. long, transverse to the weld, offered several advantages in that it is similar to the Charpy-V notch and is readily reproducible. It allows comparison of behavior of welded plate and prime plate and notches all the metallurgical structures of the weld.

The results obtained using this two-foot square specimen were compared for correlation with results from several smaller scale specimens including a standard Charpy-V type.

Residual stresses have not been measured on the two-foot square specimen but previous work by DeGarmo, Merriam and Jonassen[4] shows that for welds of length greater than 20 in., longitudinal residual stresses reach a maximum value of the yield point of the weld metal within 10 in. of either end of the weld and are constant to within 10 in. of the other end. Their work was on 1-in. plate. The work for this report was on $1^1/_4$-in. plate. The DeGarmo results are based on data from both automatic submerged-arc welds and manual welds. The same source shows unrestrained welds of the type described in this report to have high compressive transverse stresses of 30,000 psi at the ends and transverse tensile stresses of the order of 15,000 psi at the center.

Steel

Two types of carbon-steel plate were tested for this report. The first plate

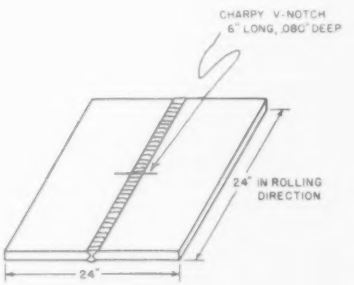


Fig. 1 Test specimen

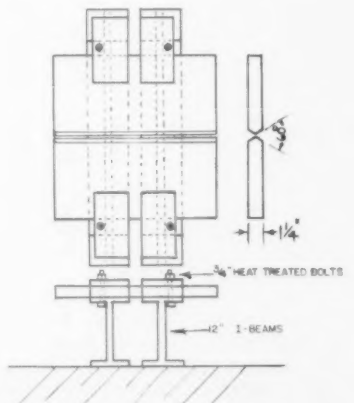


Fig. 2 Restraining method

L. J. McGeady is Head of the Department of Metallurgical Engineering at Lafayette College, Easton, Pa.

Table 1—Chemical Analysis and Mechanical Properties of A-201 Steel Plate, 1¼ In. Thick

Lehigh Data[5–8]

A. Chemical Composition

Element:	C	Mn	P	Si	S	Al
%:	0.15	0.53	0.020	0.19	0.025	0.026

B. Lehigh Bend-Test Transition Temperatures Based On 1% Lateral Contraction at Base of Notch

All welds E6010

As-rolled plate	−85° F
Welded 175 amps, 10 ipm	+43° F
Welded 275 amps, 8 ipm	+47° F
Stress relieved after welding, 10 ipm	+7° F
Stress relieved after welding, 8 ipm	+19° F

C. 0.505-In. Tensile Properties, Range from Tests of Several Plates

Elongation	30.5 to 35.1%
Reduction of area	51.1 to 64.7%
Upper yield	29,900 to 32,800 psi
Tensile strength	55,400 to 59,800 psi

D. Charpy-V 15 ft-lb Temperature −25° F

E. Lehigh Bend Test 50% Cleavage Fracture Face 95° F

F. Charpy Keyhole (½ Maximum Energy) −22 to −47° F

Table 2—Chemical Analysis and Mechanical Properties of A-212 Steel Plate, 1¼ In. Thick

A. Chemical Composition

Element:	C	Mn	P	Si	S
%:	0.29	0.73	0.017	0.20	0.033

B. Mechanical Properties*

Range from tests of several plates

Elongation	23.0 to 27.0%
Reduction of area	38.7 to 54.8%
Yield point	40,500 to 42,300 psi
Tensile strength	74,200 to 79,800 psi

C. Charpy-V, 15 ft-lb temperature +50° F

* Supplied by vendor.

used in this investigation was from a heat of steel tested extensively in previous PVRC programs at Lehigh University.[5–8] The steel was made to ASTM A-201 Grade A Specification. A summary of Lehigh data is given in Table 1.

In order to determine the behavior of a higher-strength-level steel when subjected to the several variables to be studied, a heat of steel was procured made to ASTM A-212 Grade B Flange Specification. The results of chemical analysis and mechanical tests of this steel are given in Table 2.

Welding

Welding was performed manually, under direct supervision of the author, in the Lafayette College laboratories by two expert full-time industrial operators qualified for ASME Boiler Code Work and also for other code work.

All welding was in the flat position and performed according to carefully regulated procedures. In Table 3 is given the description of welding conditions, showing number of passes, currents, etc. which were used. These conditions were familiar, acceptable and convenient to the operators, produced good electrode performance, and were readily reproducible. The currents given are measured currents, not machine settings. All beads except the root passes were put in by weaving passes layer by layer with no beads side by side, the amount of weave increasing with each succeeding pass. The welds produced were of excellent quality as judged by surface appearance, macroscopic sections and radiographic tests.

During welding, the plates were restrained from warping by being bolted to large I-beams. This technique corresponds to that used previously by the University of California[4] investigators. This is illustrated in Fig. 2. As previously stated, this procedure produces longitudinal yield-point tensile stresses at the mid-length of welds longer than about 18 in. and lower transverse tensile residual stresses at the mid-length, in value about 15,000 psi. The restraint during welding imposed in this investigation was not intended to produce weld cracking, since the tests were to be conducted on sound weldments.

Table 3—Welding Conditions, First Side Welded, EXX10 Electrode*

Pass	*Rod diameter, in.*	*Current, amp*	*Arc travel speed, ipm*
First	5/32	130	6†
Second	5/32	130	5
Third	3/16	160	4
Fourth	3/16	160	3½
Fifth	¼	220	3
Sixth	¼	220	3

* Currents for EXX16 electrode were 10 to 20 amp higher.

† This is an average figure and depends on fit-up. Second side welded at slower travel on this pass if heavy back cleaning was necessary. In some instances an extra pass of 5/32 was needed.

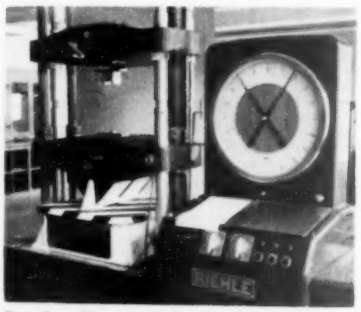


Fig. 3 Photograph of test setup

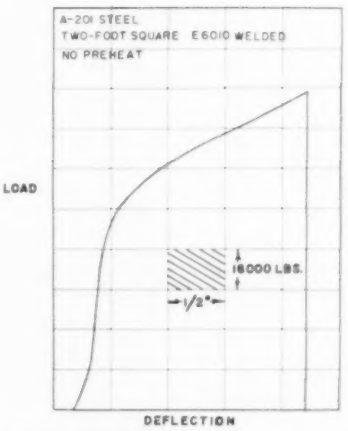


Fig. 4 Autographic curve

Specimen tested at 32° F (see Fig. 5)

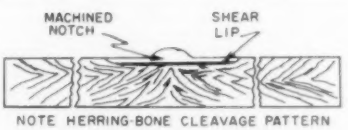


Fig. 5 Sketch of fracture of two-foot square

A-201 two-foot square E6010 welded, tested at 32° F

Following deposition of each pass, the slag was removed using a slag hammer and wire brush. The weld groove was welded full, with reinforcement, first on one side and the specimen was then allowed to cool to room temperature, after which it was removed from the restraining fixture. Then the specimen was turned over, rebolted, the root cleaned out to clean metal, and the groove welded full on the second side. The notch was then cut later in the side welded last. Notching of stress-relieved specimens was done after the heat treatment.

Preheating and Temperature Control During Welding

Three plate preheat and interpass temperatures were used in welding the A-201 steel: 125, 250 and 400° F. These plate temperatures were closely controlled. Tolerances of −50, ±25 and ±25° F, respectively, were allowed on the above nominal interpass temperatures, which were also the preheat temperatures. The 250° F preheat condition was not used on the A-212 steel.

All preheat and interpass temperatures were measured and controlled using temperature-indicating crayons. Temperature checks using a contact thermocouple to supplement those measurements served to show that actual variations in temperature were almost always much less than those given as tolerances above.

Preheating was performed by using a commercial torch, burning a mixture of natural gas and compressed air, which produced a flame about 10 in. long and about 6 in. in diam at the plate surface. The flame was not directed onto the weld metal but rather on the adjacent plate metal and was kept in continuous motion along the length of the weld in order not to heat any one spot selectively. In this way an area about 4 in. wide on each side of the full length of the weld was kept at the desired preheat and interpass temperature with a temperature gradient to the edge of the specimen. It is interesting to note that after several welding passes using torch preheat, it was not necessary to use the torch to maintain the 250° F interpass temperature, the heat of

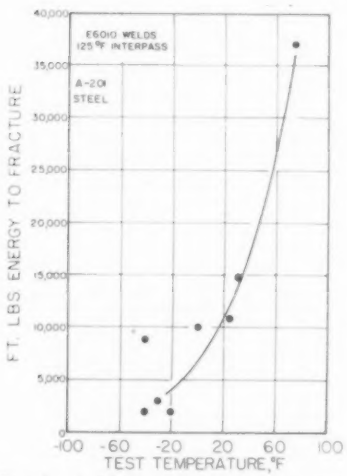


Fig. 6 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

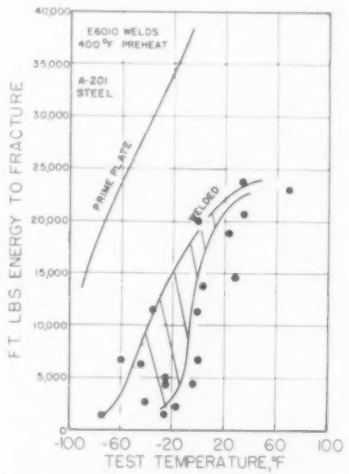


Fig. 8 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

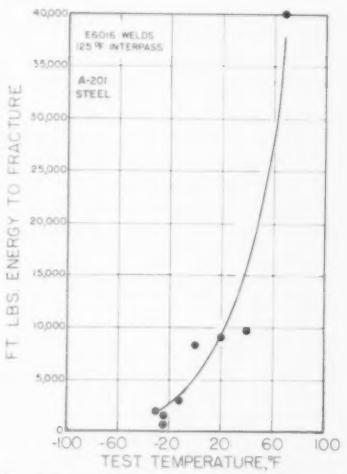


Fig. 10 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

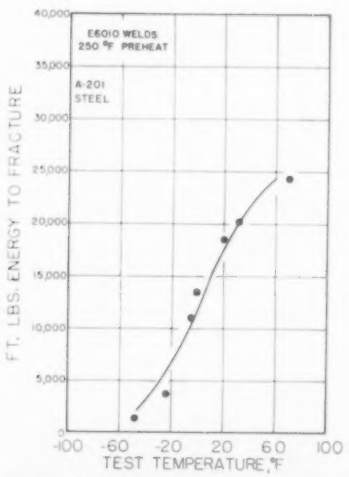


Fig. 7 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

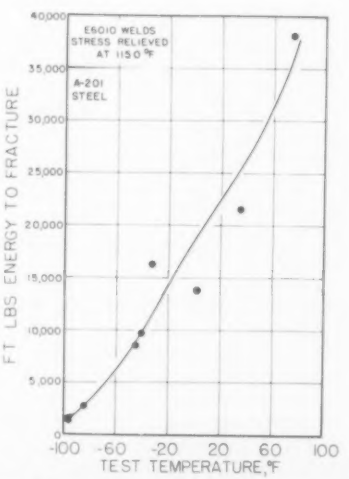


Fig. 9 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

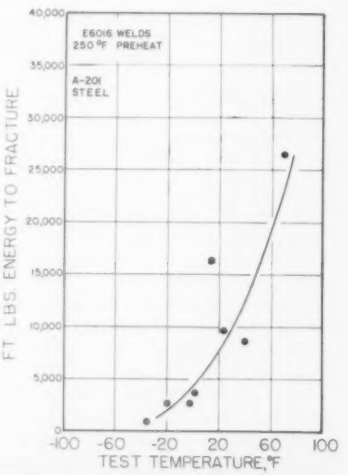


Fig. 11 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

Table 4—Transition Temperatures of Two-Foot Square Specimens Based on 10,000-Ft-lb Energy Absorption

Condition	A-201 steel		A-212 steel	
	E6010 welds	E6016 welds	E7010 welds	E7016 welds
125° F maximum interpass	+15° F	+25° F	+60° F	+60° F
250° F interpass	−10° F	+25° F	...	...
400° F interpass	−5 to −40° F	+20° F	+60° F	+60° F
1150° F stress relief	−40° F	−40° F	...	...
Unwelded plate	(Approximately	−100° F)	−30° F	−30° F

Table 5—Transition Temperatures of Two-Foot Square Specimens Based on ½-In. Deflection at Failure

	A-201 steel		A-212 steel	
	E6010 welds	E6016 welds	E7010 welds	E7016 welds
125° F maximum interpass	−25° F	−20° F	+20° F	+15° F
250° F maximum interpass	−40° F	−20° F	...	...
400° F maximum interpass	−20° F to −80° F	−20° F	+30° F	+20° F
1150° F stress relief	−80° F	−80° F	...	...
Unwelded plate	Approx.	−100° F	−80° F	−80° F

welding alone keeping the temperature high enough. Continuous heating was necessary to maintain the 400° F preheat and interpass temperature. To maintain an interpass temperature between 75 and 125° F, it was necessary to allow the plate to cool in air a considerable length of time after all except root passes.

Although on most specimens, welding on one side was started and finished at one session (meaning that, say a 250° F temperature was maintained from start to finish of welding on one side); on several A-201 plates only three or four passes on one side were put in during one day due to unforeseen circumstances. These specimens were allowed to cool to room temperature overnight. The next day the preheating torch was used to reheat to 250° F before welding was resumed. This procedure does not affect the results obtained and corresponds to the handling of welds by the University of California investigators.[4]

Electrodes Used

Two AWS classes of electrodes, E6010 and E6016, were used to weld the A-201 specimens. The E6016 electrode supplied also meets E7016 specifications. The individual types of electrodes were secured from separate nationally known manufacturers. Both electrodes were shipped to the laboratory, fresh, in paper-type containers. They did not get wet and were stored immediately in the laboratory building in a dry inside room thermostatically controlled at 70° F. The supplier of the E6016 recommended that the electrodes be used fresh as supplied without any heating for drying and, further, would not suggest a temperature if such heating should be done. The definite instruction was that keeping the electrodes away from rain, or other obviously liquid forms, by careful storage was quite adequate handling precaution for the E6016 electrode. It will be shown later that heating this electrode at 400° F prior to welding produced no benefit.

The electrodes used to weld the A-212 steel specimens were to E7010 and E7016 AWS specifications. The E7016 electrode was supplied by the same manufacturer as the E6016 electrode and was the same electrode since, as has been stated, the electrode meets both E6016 and E7016 specifications. This electrode was again shipped from the manufacturer, fresh, to the welding laboratory where it was stored immediately in an oven at 400° F until use.

The E7010 electrode came from a third manufacturer shipped in crimp-sealed metal cans.

Radiography

Radiographic examination of all welded specimens was performed by the staff of the Ingersoll-Rand Co. at their Phillipsburg, N. J. plant. The radiography was performed with an 1120 millicurie source of Cobalt 60 at a distance of 48 in. for fifteen hours. No flaws were found of severity significant enough to warrant rejection. Inspection of films was performed by standard techniques.

Stress-Relief Heat Treatment

Thermal stress relief was performed by the Ingersoll-Rand Co., using a standard ASME treatment for pressure vessels of carbon-steel plate. This consisted of heating to 1150° F, holding two hours at temperature, furnace cooling to 600° F, and then cooling in still air. An oil-fired furnace with hearth dimensions, five by ten feet, and arch height of five feet, was used.

Table 6—Deflection and Load-Carrying Characteristics of Two-Foot Squares Tested in Bending at Various Temperatures, A-201 Steel, E6010 Electrode

Test temperature, ° F	Yield load, lb	Max load, lb	Deflection at failure, in.
A. Weld-Interpass Temperature, 125° F max			
−40	72,000	128,000	0.4
−30	72,000	85,000	0.5
−20	64,000	80,000	0.35
0	70,500	81,700	2.0
24	68,000	111,000	1.4
32	64,000	120,000	2.0
75	72,000	108,800	4.6
B. Weld-Interpass and Preheat Temperature, 250° F			
−60	...	92,000	...
−48	65,000	81,250	0.35
−23	84,500	97,000	0.65
−4	76,375	87,000	1.80
0	73,125	121,000	1.80
21	69,875	130,200	2.4
32	65,000	101,000	2.2, 3.5
70	68,250	135,000	3.0
C. Weld-Interpass and Preheat Temperature, 400° F			
−75	78,000	89,300	0.3
−61	81,500	106,000	1.1
−60	82,875	108,000	1.1
−44	73,125	104,000	1.05
−40	78,800	91,400	0.5
−40	...	97,500	0.5
−35	73,125	114,000	1.6
−24	82,000	114,800	0.4
−28	71,500	102,000	0.85
−25	68,000	88,500	1.4
−23	74,800	79,800	...
−18	73,500	86,400	0.5
−10	82,650	115,700	0.8
−4	68,000	98,600	...
0	73,500	122,000	1.1
0	66,625	102,800	2.15
25	71,500	110,500	2.2
34	65,000	125,125	2.8
70	69,875	120,000	2.8
D. Specimens Stress Relieved After Welding			
−100	97,500	104,000	0.2
−85	99,125	102,300	0.45
−45	79,625	111,600	1.15
−40	...	124,000	1.5
−40	89,375	110,300	1.8
−33	87,150	123,500	2.1
2	77,188	126,000	1.85
35	78,000	144,000	2.30
75	69,875	133,500	4.2
E. Unwelded Plate			
−90	103,000	122,000	1.2
−85	96,000	133,000	2.0
−50	93,500	137,800	3.0
−30	83,000	138,800	3.4
−5	67,000	143,800	4.5
16	78,250	138,800	3.0

Method of Testing

Specimens were brought to desired testing temperatures by immersion in baths of alcohol or kerosene which were cooled if necessary by dry ice. The tank used was 32 in. square, 10 in. deep. The specimens were held horizontally three inches off the bottom, for circulation of the liquid and temperature uniformity. Temperatures were measured using ASTM code-tested, immersion type, glass thermometers, placed at four points in the bath with spot checks at various areas immediately prior to testing. Specimens were then transferred to the testing jig, notched side down, and tested by bending as beams supported at the ends. The test span was 18 in. Fracture was transverse to the weld. Load was applied at a rate of head movement of two inches per minute. The jig used was of the type used for the Kinzel but proportioned to the size of specimen used here. During the testing, an automatically recorded load-deflection curve was obtained for each specimen. Fracture characteristics were noted after the tests were completed. The testing setup is shown in Fig. 3. A typical load-deflection curve is shown in Fig. 4.

Criterion of Brittleness; Selection of Transition Temperature

Problems common to all investigations of notch toughness are determination of the number of specimens which should be tested, what criterion of transition temperature should be used, and, having selected the criterion to measure, what absolute level of that criterion shall be chosen to designate transition temperature. These problems are further complicated by the well known fact that as more and more specimens are tested the amount of scatter in data may increase. When scatter does result, transition temperature can be given as a temperature range or as a single temperature chosen at the middle of the scatter range. In this investigation, the problem has been met by drawing scatter bands in the plotted curves only when the amount of scatter is appreciable; in other cases where scatter is comparatively slight, single average curves are drawn through the plotted points.

In appreciation of the fact that there are many ways to select the transition temperature, the entire collection of data on the two-foot square specimens in these tests in respect to deflection at failure, loads carried, and energy absorbed in fracturing has been presented. However, only energy absorption data have been plotted against temperature, and plots for the A-201 steel only are given. All other data are tabulated. For purpose of discussion, a level of energy absorption of 10,000 ft-lb to fracture has been selected as the comparative measure of the transition temperature in these tests. Another value of energy absorption might be chosen for comparison, say 7500 ft-lb, but the order of rating of the specimens would be essentially the same with about the same degree of difference among the various conditions. If deflection at failure is used as the measure of specimen performance, a suitable transition temperature is that at which $^1/_2$-in. deflection occurs for each of the conditions tested in this investigation.

The fracture-appearance transition temperature was not developed for either steel since there was insufficient steel and it was not felt necessary to do so. Most investigators have agreed that fracture appearance offers little advantage as a measure of transition temperature and that it is an unrealistic one for comparison with service performance. The temperature at which fracture changes from predominantly shear to predominantly cleavage changes very little with specimen geometry and generally occurs at rather elevated temperatures. In the tests made for this report on A-201 and A-212 steels, the severe drops in ductility and energy absorption occurred in a temperature range where the fracture appearance shown by these steels is almost completely cleavage. This is in accord with usual findings on steels of this kind, namely that the temperature at which fracture appearance changes from predominantly cleavage to predominantly shear is quite high, usually room temperature or higher. The Lehigh data in Table 1 (E.) show a fracture transition temperature in the Lehigh bend test at 95° F for the A-201 steel. No tests for this report were made on the A-201 steel at that high a temperature, where it would be expected that fracture appearance would change in tests of this specimen, since the ductility transitions which were sought occurred at considerably lower temperatures.

Because a reduced-size photograph of a fracture specimen face would be of little value in appropriate size for inclusion in this report, a sketch of a typical fracture has been given in Fig. 5 indicating that directly under the notch some shear-type fracture appears. The amount of shear decreases with decreasing temperature of test.

Effect of the Variables Studied

A-201 Steel

Considering only E6010 weldment data, using the two-foot square specimen, the effects of preheat can be seen in Tables 4 and 5. It appears that with the particular specimen and notch used here that the effect of preheating at 250° F for welding with E6010 electrode is very moderate but nevertheless detectable (Figs. 6 and 7). The scatter in results obtained from specimens preheated to 400° F is not readily explained (Fig. 8); those specimens which give best performance show almost as much improvement as is gained by stress relief (Fig. 9). It is important to note that some noticeable improvement occurs with preheating or stress relieving using any of the three bases of measurement—energy absorption (Fig. 6 vs. Figs. 8 and 9), deflection at failure,

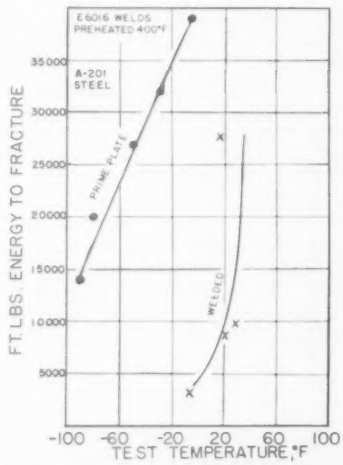


Fig. 12 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

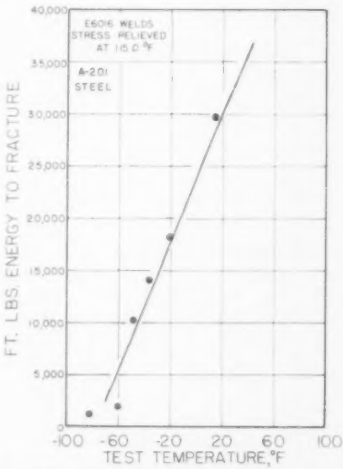


Fig. 13 A-201 steel, two-foot squares, energy to fracture as influenced by temperature

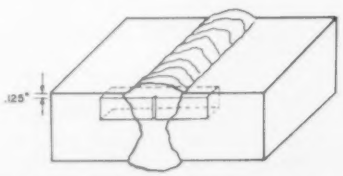


Fig. 14 Method of taking weld-metal Charpy bars

or load-carrying ability (Tables 5 and 6). In general, the data given here tend to support the findings of other investigators who find preheating beneficial to notch toughness of E6010 and E6020 weldments, but there is significant difference between the two-foot square specimen tests for this report and the Columbia beam tests or the hatch-corner tests in that the failure in the tests for this report were through both the weld metal and welded base plate, whereas the Columbia and California failures were largely confined to the weld metal.

In the two-foot square specimens, for this investigation, a notch was used and placed transverse to the weld, cutting through the weld metal and into the adjacent base plate with its heat-affected zone. These constraint conditions favor early cracking at the center of the plate span during testing and failure is forced to initiate at the weld, but total failure (taken as destruction of the entire testpiece) may not occur simultaneously with failure of the weld. Therefore, the specimen and notch used determine at what temperature a crack formed in a notched weld will run in a notched plate rather than in weld metal or in unnotched plate.

Considering the E6016 weldment data and the A-201 steel in Tables 4 and 5, it is seen that the behavior of the nonpreheated specimens (75 to 125° F interpass) is essentially the same as that of nonpreheated specimens welded with E6010 electrodes. Table 4 gives the transition temperatures as +15° F for E6010 welds and +25° F for E6016 welds based on energy absorption. This difference of 10° F should not be considered significant since curve drawing could account for that difference. It should be noted, however, that preheating to 250 or 400° F does not improve the transition temperature of the E6016 weldments of A-201 steel as shown in Tables 4, 5 and 7 and Figs. 10, 11 and 12. As stated previously, the original batch of electrodes was not given any special handling for welding at 125° F interpass or 250° F preheat. The question then developed since it was anticipated that the E6016 weldment results would be better than the E6010 results, whether these E6016 welds were defective in some way. It was suggested that the electrodes might not have been dry or fresh enough or that they were being improperly handled. Therefore, a series of two-foot square specimens was welded with E6016 electrodes which had been heated at 400° F for 48 hr before welding. Inadequate supply of the A-201 plate did not allow enough specimens to develop the curves of Fig. 12. However, the results obtained are substantiated by tests reported here using the Charpy-V specimens.

Stress-relief heat treatment produces identical results in the E6010 and E6016 weldments. Although stress-relief heat treatment lowers the transition temperature markedly, the transition temperature remains higher than that of unwelded specimens (Tables 4 and 5; Figs. 8 and 9).

Effect of the Variables Studied

A-212 Steel

Results of testing two-foot squares of

Table 7—Deflection and Load-Carrying Characteristics of Two-Foot Squares Tested in Bending at Various Temperatures, A-201 Steel, E6016 Electrode

Test temperature, ° F	*Yield load, lb*	*Max load, lb*	*Deflection at max load, in.*
A. Weld-Interpass Temperatures, 125° F max			
70	...	110,500	4.25
40	65,000	127,000	2.60
20	70,000	88,000	1.50
0	71,500	93,000	1.50
−12	65,000	93,500	0.60
−24	75,500	82,500	0.15, 0.45
−30	73,125	91,500	0.4
B. Weld-Interpass and Preheat Temperatures, 250° F			
70	65,000	139,500	3.0
40	65,000	87,000	1.5
24	66,500	99,500	1.6
16	65,000	98,000	2.35
+2	65,000	78,000	0.8
−2	...	58,000	0.9
−20	65,000	84,500	0.5, 1.0
−35	70,000	85,000	0.35
C. Weld-Interpass and Preheat Temperatures, 400° F			
28	61,500	90,500	1.55
22	70,000	102,000	1.4
16	65,500	100,000	4.0
−8	72,000	77,500	0.8
D. Specimens Stress Relieved After Welding			
−82	86,000	90,000	0.35
−60	85,500	85,500	0.40
−48	83,000	112,000	1.45
−35	81,000	118,000	2.00
−20	73,000	128,000	2.45
+14	70,000	131,000	3.50
+70	65,000	158,000	4.20

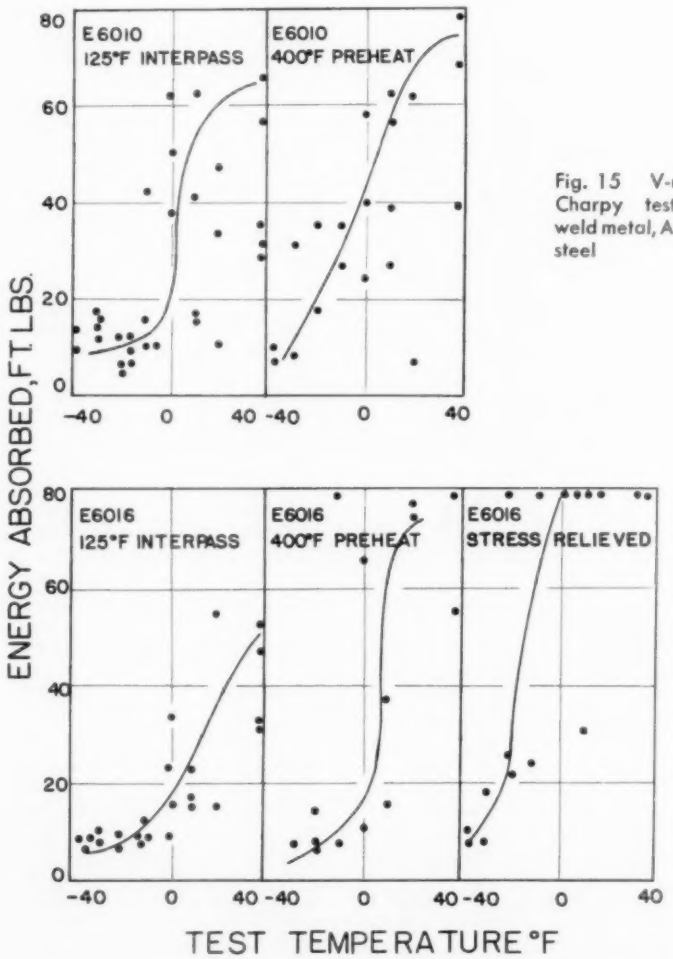


Fig. 15 V-notch Charpy tests of weld metal, A-201 steel

A-212 steel are shown in Tables 4, 5 and 8. It is readily seen that neither preheating nor type of electrode used affected transition temperature of these weldments. As was the case for the tests of A-201 steel, it is clearly shown that welded specimens have significantly higher transition temperatures than the nonwelded prime-plate specimens. It is apparent too that, using energy absorption and deflection to failure as the criteria for selection of transition temperature, the A-212 heat of steel has uniformly higher transition temperatures than the A-201 steel. Table 8 shows the A-212 steel to have greater load-carrying ability than the A-201 steel in Tables 6 and 7 at the temperature tested. No interpretation of this is offered since it is expected behavior.

Interpretation of the Results

From extended preliminary discussion of this paper, prior to submission for publication, it was evident that it is widely believed that E6016 weld deposits are much more notch tough than E6010 weld deposits. Actual published data to support this general belief have not been found. It is common knowledge that the "toughness" of low-hydrogen electrode welds during fabrication under many circumstances exceeds that of cellulose-coated electrodes but toughness of that kind is not what is under consideration in this report. However, there is not necessarily any correlation between the kind of toughness that manifests itself as resistance to weld cracking during fabrication and the kind of toughness investigated for this report, namely notch toughness. Therefore, this report does not deal in any way intentionally with effects of preheating on fabrication of weldments, although, as stated earlier, it is possible that some of the same factors which prevent fabrication cracking of weld metal might also help produce greater notch toughness of the finished weldment.

From the various tests conducted for this report, data have been given to show and compare the effect of variations in procedures. From the plots and criteria of transition, transition temperatures have been selected and tabulated for the various testing conditions. Where change in transition temperature occurs, the decision remains to be made as to significance of changes of various magnitudes. The decision becomes difficult when the scatter inherent in all notched-bar tests is considered. It is well known that great numbers of tests may result in extremely wide scatter zones when the data are plotted. In Charpy-V tests it has been shown for example that the scatterband for the A-201 steel used in this investigation is 50° F wide over a large part of the curve. Considering this, the significance of a change of 10 or 20° F in average transition temperature in the Charpy-V test is very questionable. Similarly, in other tests it is important to know how large a difference in transition temperature should be to be considered significant.

Consequently, from the results of this investigation, although preheat for welding with A-201 steel produces transition temperature changes, it must be emphasized that since the changes produced may be considered small, they may well be of minor importance. Likewise, Tables 4 and 5 show the detected differences in transition temperature, brought about by use of the various electrodes, may not be great enough to be of any real significance.

Because the specimen used for these tests was new and because it was anticipated that a large specimen would elim-

Table 8—Data from Two-Foot Square Tests of A-212 Steel

Test temperature, ° F	*Yield load, lb*	*Max load, lb*	*Deflection at failure, in.*	*Energy to failure, ft-lb*
A. Weld-Interpass Temperature, 125° F max				
140*	80,000	137,500	6.00	54,000
123	82,000	138,500	6.00	58,000
95*	79,500	163,000	2.40	12,000
81	77,500	138,500	1.48	12,000
75	80,000	112,000	1.30	7,200
60	85,000	113,000	0.75	8,300
50	80,000	108,000	0.42	6,000
40	76,000	96,000	0.74	4,000
30	72,000	95,500	0.79	4,500
30	85,000	109,000	0.35	8,000
20	81,500	109,000	0.85	5,000
15	75,500	99,000	0.43	1,900
0	82,000	101,500	0.43	1,800
−24	82,000	98,500	0.30	1,600
−40	90,000	112,000	0.50	3,000
−60	98,000	104,200	0.30	1,700
		E7016 welded		
81	77,500	131,500	1.43	11,350
68	80,000	146,500	1.70	15,160
53	76,000	110,500	1.20	7,600
40	84,000	108,500	0.96	5,500
30	81,500	133,500	1.20	9,000
30	85,000	119,000	0.75	5,300
25	78,500	135,000	1.23	10,200
15	82,500	105,500	0.50	2,400
0	81,000	102,000	0.88	3,650
B. Weld-Interpass Temperature, 400° F				
		E7010 welded		
115	72,000	152,000	4.00	48,000
105	72,000	153,000	4.00	44,000
95	74,000	155,000	3.20	28,700
75	80,000	121,500	1.50	9,000
66	80,000	100,500	0.45	2,800
46	77,000	120,000	1.1	8,000
20	80,000	99,000	0.5	2,000
0	79,000	102,000	0.5	2,500
		E7016 welded		
75	67,500	132,000	2.00	12,000
68	77,000	121,000	1.35	6,400
58	72,000	105,500	0.95	6,000
42	77,000	93,000	0.45	12,000
40	80,000	133,000	1.20	10,260
30	80,000	132,500	1.15	9,200
20	80,000	104,000	0.45	2,300
4	77,000	91,500	0.35	1,100
C. Unwelded Plate				
10	88,000	148,400	2.00	18,000
−10	96,000	139,500	1.35	10,400
−20	88,000	128,500	1.10	10,500
−35	101,000	137,500	1.10	10,000
−60	101,000	125,000	0.90	6,700
−75	108,500	135,000	0.90	7,300
−100	112,000	121,500	0.31	1,200

* Specimen did not fail.

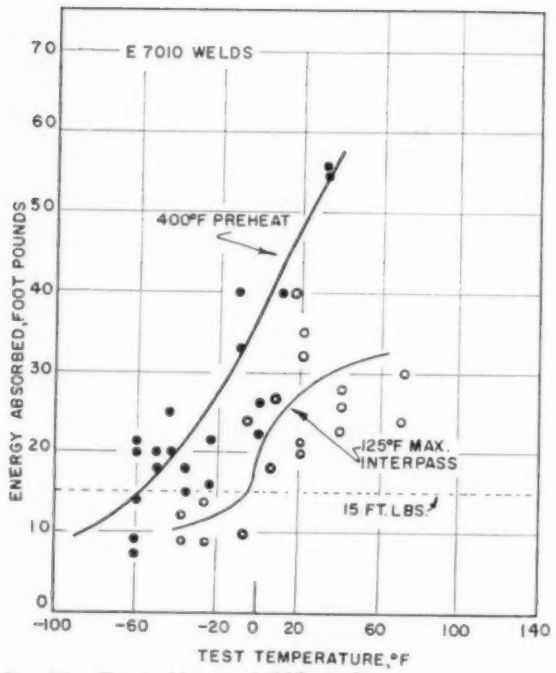


Fig. 16 Charpy-V tests, A-212 steel

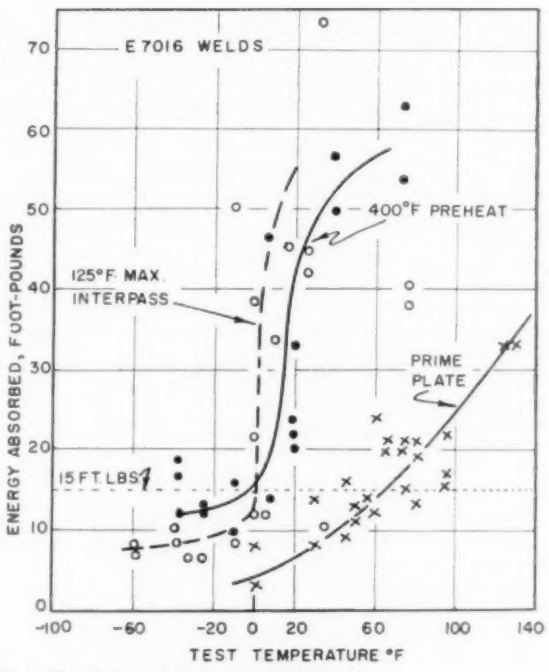


Fig. 17 Charpy-V tests, A-212 steel

inate scatter in transition temperature testing, the data needed confirmation. Confirmation by a standard test procedure was needed also because the E6016 electrode welds did not produce the anticipated superiority in results over the E6010 welds. For this reason an extensive program was undertaken to check the results obtained using the two-foot squares. Briefly, all these tests (transition-temperature tests on smaller specimens) confirmed the findings using two-foot squares. Of these tests, only the Charpy-V will be described here.

Charpy Tests of Weld Metal

It was thought desirable to confirm further the results from tests of the two-foot square specimen using a common standard test but utilizing the welds originally tested in the two-foot square specimens. To accomplish this, Charpy-V test bars of standard dimensions were taken from undeformed sections of the two-foot square specimens as shown in Fig. 14. This produced a bar which, when tested under standard impact, fractured entirely through weld metal. However, this is not a standard AWS test bar and the weld metal here is considerably more diluted with the base plate than is the case in the suggested standard test. Also it must be remembered that the standard test weld is made with a 212° F interpass temperature. Consequently, the transition temperatures obtained from the tests in this investigation should not be viewed necessarily as representative of those to be obtained from the suggested standard.

The curves given by these Charpy tests are shown in Fig. 15 for the A-201 steel and in Figs. 16 and 17 for the A-212 steel, and the transition temperatures taken at 15 ft-lb are given in Table 9. Again because of the large number of test specimens used, considerable scatter resulted. In general, the Charpy results confirm those obtained from the two-foot square specimens using A-201 steel. For both steels and electrodes, preheat improves the transition temperature of the EXX10 weld metal. Preheat did not result in an improved transition temperature in the EXX16 weld metal. The EXX10 weld metal deposited without preheat has as low a transition temperature as EXX16 weld metal deposited under the same conditions.

It is noteworthy that using the A-201 steel the 15 ft-lb transition temperature for the E6010 weld metal preheated to 400° F and for the E6016 weld metal stress relieved is the same as that found by the Lehigh University investigators for the unwelded plate in Table 1. This raises the question as to why, when using two-foot square specimens, the stress-relieved specimens are not equal in notch toughness to the unwelded specimens. The answer probably lies in the fact that the Charpy-test specimens contained none of the coarse columnar grains of the last pass of weld metal, while in the two-foot square specimen the notch lies in the last pass. Thus,

Table 9—Transition Temperatures of Weld Metal and Base Plate

Charpy Specimens Taken at 15 Ft-lb Energy Absorption

Welding condition	*Transition temperature, ° F A-201 steel*	*A-212 steel*
EXX10 welded—125° F interpass	−5	−10
EXX10 welded—400° F preheat	−25	−50
EXX16 welded—125° F interpass	−5	0
EXX16 welded—400° F preheat	−5	0
EXX16 stress relieved—1150° F	−25	..
Base plate—unwelded	−25	+50

Table 10—Weld-Metal Compositions

(Taken from All-Weld-Metal Pads)

Electrode	*Supplier*	*Rod Diameter, in.*	*C%*	*Mn%*	*Si%*
E6016	A	5/32	0.10	0.48	0.76
E6016	A	1/4	0.10	0.51	0.44
E6016	B	5/32	0.07	0.78	0.77
E6016	B	1/4	0.06	0.65	0.62
E6010	C	5/32	0.07	0.30	0.13
E6010	C	1/4	0.08	0.34	0.13

even though stress relief undoubtedly toughens this last pass a great deal, it cannot entirely overcome the undesirable feature of coarse grains in last-pass weld metal and heat-affected zone.

Microstructures

A typical weld macrophotograph is given in Fig. 18 along with typical microstructures of various weld areas. The microstructures are what would normally be expected in this kind of joint. As each pass is deposited, it affects the metal upon which it is made, tending to produce all the well-known heat effects. In welding by multiple-pass technique, some of the functions of heat treatment are performed. Where the welding takes place on previously deposited weld metal, the weld metal being deposited on is heated, some to such temperatures within the austenite range that subsequent cooling eliminates the undesirable columnar weld-metal structure and produces in its place an equiaxed fine-grain structure. Likewise, some of the solid weld metal being reheated may be heated to temperatures not high enough to cause recrystallization but high enough to give partial stress relief. The area so affected may be somewhat increased in notch toughness.

Virtually all the weld-metal specimens taken for microscopic examination showed that all passes except the last on each side had been almost completely recrystallized by succeeding passes. The last pass showed typical columnar-grain structure. The grains at the fusion line in the base metal are similarly affected by heat of succeeding passes. Those that are made coarse during deposit of the adjacent metal can be refined in deposition of succeeding passes; such refining occurred to the specimens in this investigation. It was observed, and is shown in Fig. 18, that E6016 weld metal tends to be slightly finer grained than E6010 weld metal. A variety of grain sizes is found, however, in any weld.

Comparison of Results with Those of Other Investigations

Pellini and Eschbacher,[9] reporting on the ductility transition of weld metal drop-weight tests (using full butt-welded plates notched transverse to the weld in the weld-metal reinforcement only), determined transition temperatures for E6010, E6020, E6030 and E-7016 welds. Transition temperatures for E6010 welds ranged from −10 to +20° F; for E7016 ranged from 0 to +20° F. It could be said that since a difference in transition temperature of 10° F is of very questionable significance in the drop-weight test, the E6010 welds are perhaps only very slightly less notch sensitive than the E7016 welds.

Krefeld and Anderson,[2] reporting on tests of welded beams, give their results of their tests in the following tabular form:

Each transition temperature is taken from the results of 4 test specimens at most. It is apparent, if the data of this table are valid, that preheat using E6011 and E6020 electrodes lowers transition temperature. In the case where E6016 was not moisture controlled, preheat for welding improved the transition temperature over that of nonpreheated specimens. In another series of tests with a different E6016 electrode and moisture controlled, the data show the transition temperature is made poorer by use of preheat. It should be noticed that the transition temperature of the specimens welded with the low-hydrogen electrode termed moisture controlled is lower than that of specimens welded with electrodes termed nonmoisture controlled. The authors state that, possibly, the nonmoisture-controlled electrodes produced a higher weld-metal hydrogen content than the weld metal produced by welding with the low-hydrogen moisture-controlled electrodes. However, they state that no determinations of weld-metal hydrogen were made. It is very possible that the difference in behaviors exhibited by the

Effect of Type of Electrode on Transition Temperatures, ° F, of Butt-Welded Structural Beams

	Type of electrode		
Type of steel, weld treatment	*E6011, E6020*	*E6016, no moisture control*	*E6016, moisture controlled*
Semikilled			
As-welded	−5	−25	..
Preheat	−17	−36	..
Stress relieved	−5	..	..
Fully killed			
As-welded	−29	−15	−65
Preheat	−57	−35	−55
Stress relieved	−45	..	..

Table 11—Vickers Hardness Numbers, 5 Kg Load, Diamond Pyramid, A-201 and A-212 Plate, 1 1/4 In. Thick, Multiple-Pass Butt Welds

	125° interpass			*250° F preheat*		*400° F preheat*		*Stress relieved*		
Position	*Weld*	*Heat-affected zone*	*Plate*	*Weld*	*Heat-affected zone*	*Weld*	*Heat-affected zone*	*Weld*	*Heat-affected zone*	*Plate*
A. E6010 Welds: A-201 Plate										
0.080 in. below surface	131	140	118	128	135	128	128	102	129	106
Midway to center	110	128	115	111	131	108	128	99	108	104
Center	131	137	126	135	138	137	151	110	125	106
B. E6016 Welds: A-201 Plate										
0.080 in. below surface	145	145		131	138	153	130	131	120	106
Midway to center	131	129		131	131	148	131	118	124	104
Center	156	160		153	153	153	142	129	138	104
C. E7010 Welds: A-212 Plate										
0.080 in. below surface	161	178	140							
Midway to center	140	165	138							
Center	178	165	138							
D. E7016 Welds: A-212 Plate										
0.080 in. below surface	150	165	131							
Midway to center	138	159	140							
Center	159	168	131							

specimens prepared with the two types of E6016 was due, not to hydrogen differences but to welding techniques or weld-metal composition or other factors.

Flanigan, Bocarsky and McGuire,[10] in results of a WRC supported program, report that hydrogen has a pronounced effect on the ductility of welds. Using a notched-bend test, they report test results which clearly demonstrate that when the cooling rate of E6010 weld metal is retarded at 400° F, remarkable improvement in ductility results. The paper demonstrates very clearly that variation of the cooling rate below 400° F had no influence on the ductility of E6016 welds. Slowly cooled E6010 welds had ductility at least as good as E6016 welds at −100° F. The E6016 electrodes used were baked at 800°F prior to welding. An outstanding implication of this work is that preheat to 400° F will result in low rates of weld cooling following welding and allows time for release of hydrogen. Such release improves ductility in E6010 welds but in E6016 welds, if hydrogen content is low, very little can be released in cooling and thus ductility cannot be improved to any marked extent.

Chemical Analysis of Weld Metal

In order to attempt to explain the similarity in behavior of the two types of electrodes when used without preheat, all weld-metal pads were built up on the A-201 plate to a height of one inch. From these pads, drillings were taken for chemical analysis by a commercial firm's laboratories accustomed to running such analyses in great number daily. The results of these analyses are given in Table 10. The purpose of these chemical analyses was to check to see that there was nothing unusual about the composition of deposit produced by these electrodes. These compositions correspond to the manufacturer's typical analysis and also explain the slightly higher hardness of the E6016 weld metal given in Table 10.

Summary

Bend tests of welded flat-plate specimens, one and one-quarter inches thick and two-feet square, have been made using a heat of A-201 Grade A steel. The weld was a full butt joint down the length of the specimen, long enough for yield-point residual stresses to be set up in the weld metal. Plates were welded without preheat and with preheats of 250 and 400° F. Two electrode types were used, E6010 and E-6016. Several series of plates welded without preheat were thermally stress relieved. Two-foot squares of unwelded plate were tested. Supplementary tests on specimens of other geometry were made to check the data from the square specimens.

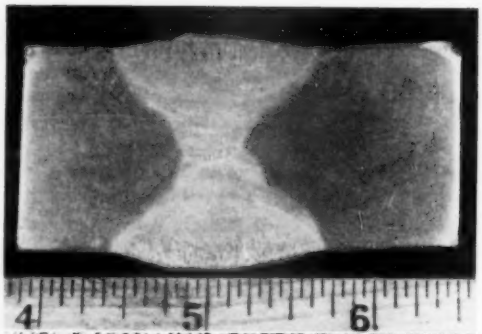


Fig. 18A Macrostructure of typical E6016 weld without preheat

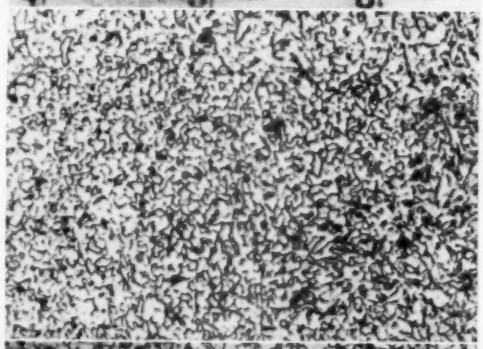


Fig. 18B E6016 weld metal halfway from top to center of plate. (No preheat) X120

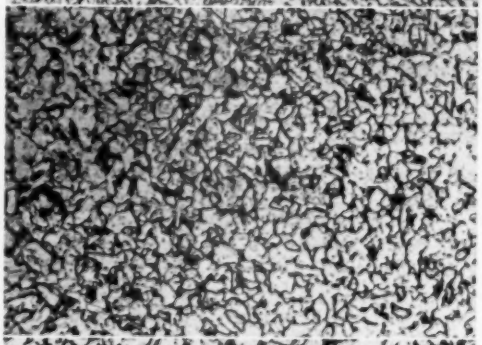


Fig. 18C E6016 weld metal halfway from top to to center of plate. (250° F preheat) X120

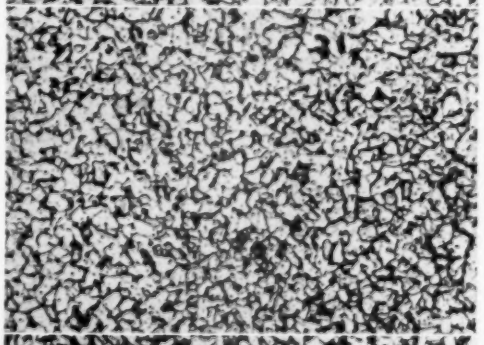


Fig. 18D E6010 weld metal halfway from top to center of plate. (No preheat) X120

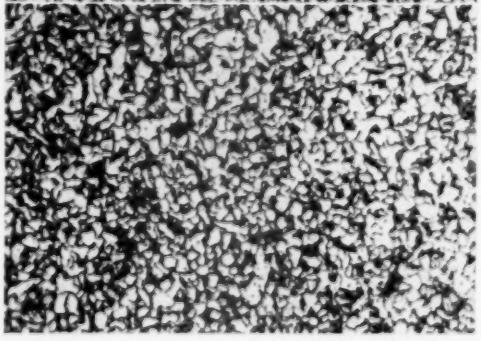


Fig. 18E E6010 weld metal halfway from top to center of plate. (400° F preheat) X120

A heat of steel to ASTM, A-212 Grade B, has been tested in many of the above tests. It cannot be emphasized too strongly that the results obtained are not necessarily indicative of the behavior of these two steel types in general. It is well known[11] that in notched-bar tests there can be wide variation in performance among several heats to the same specification. Similarly, the electrodes used have been procured as stated, one each from three manufacturers and these too may vary in notch toughness from heat to heat and according to manufacturer.

With these limitations in mind, conclusions are drawn as follows:

1. A specimen has been developed which, while being large enough to contain significant residual stresses and to simulate commercial weldments in other ways, can be used conveniently as a laboratory test specimen.

2. The specimen, although it does not eliminate the scatter of data inherent in all notched-bar testing, is not more susceptible to scatter than other commonly used tests.

3. Specimens of A-201 steel welded with E6010 electrodes without preheat behaved very similarly to specimens welded with E6016 electrodes without preheat.

4. Using A-201 steel and E6010 electrodes, preheat improved transition temperature of two-foot squares.

5. Using A-201 steel and E6016 electrodes, preheat did not improve transition temperature of two-foot squares.

6. Essentially identical performance was obtained on two-foot squares of A-212 steel welded with E7010 and E7016 electrodes, with and without preheat.

7. Stress-relief heat treatment lowered the transition temperature of welded A-201 squares from 15° F (E6010) and 25° F (E6016) to −40° F for both electrodes.

8. Unwelded base plates had the lowest transition temperatures of all two-foot squares, −100° F for the A-201 steel and −30° F for the A-212 steel.

9. None of the variations, preheat or thermal stress relief, caused as much difference in transition temperature as exists between the materials A-201 steel and A-212 steel in comparable conditions, welded or unwelded.

10. Nonpreheated E6010 weld-metal Charpy-V tests from A-201 plate showed the same transition temperature (−5° F) as E6016 weld-metal Charpys. This transition temperature is essentially the same as that obtained from E7010 welds (−10° F) and E7016 welds (0° F) obtained on A-212 plate.

11. The transition temperature of various weld-metal Charpys from A-201 specimens was higher than that of the base plate (−25° F). In the case of A-212 specimens, the weld-metal Charpys had a lower transition temperature than the base plate (+50° F).

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(Continued on page 569-s)

POSTHEAT TREATING WELDMENTS WITH AN EXOTHERMIC MATERIAL

Laboratory investigation and actual shop and field applications indicate that 5% Cr – 0.5% Mo wrought-pipe weldments can be successfully postheat treated with an exothermic material

BY M. F. SHEELY AND B. L. LACEY

ABSTRACT. The investigation reported herein represents the results to date of a continuing program which is intended to develop further the application of an exothermic material as a postheat-treating medium. The application presently concerns welded butt joints in 5% Cr-0.5% Mo wrought pipe fabricated with matching electrodes.

The application of an exothermic material that will bring metal temperature above the lower critical transformation-temperature range of the steel has been developed. Consistently satisfactory reductions of the as-welded hardness of 5% Cr–0.5% Mo pipe weldments are obtained.

The simplicity of this method of postheat treating indicates that considerable savings can be effected through the use of the exothermic material as compared with conventional field postheat-treating methods.

Introduction

With refinery processes going to higher pressures and temperatures, the demand for piping and tubing capable of severe operating conditions has increased the use of the low chromium-molybdenum steels. These steels, when fabricated by welding with matching electrodes, develop high as-welded hardness in the weld and heat-affected zones. Therefore, postheat treatment is usually required to transform the hard as-welded structure to one possessing more suitable engineering properties.

Postheat treatment in the field is generally conducted by electric resistance or induction methods and, when properly applied, have proven satisfactory. However, they are frequently costly, require considerable time to heat treat a joint, and are limited in the number of joints that can be heat treated simultaneously. An exothermic material that would be simple to apply, that could be applied to any number of joints simultaneously and was economical in cost, would have considerable application in postheat treating weldments fabricated of the low chromium-molybdenum steels. This newer concept, the application of an exothermic material as a postheat-treating medium, is the theme of this paper.

M. F. Sheely is Engineering Associate and **B. L. Lacey** is Metallurgical Engineer associated with Esso Research and Engineering Co., Linden, N. J.

Experimental Procedure

Materials

Random lengths, approximately 10 to 12 ft each, of ASTM A 335–55T Grade P5 Class of pipe material were used. The chemical analyses of the pipe used are as follows:

Fig. 1 Half cylinder of exothermic material

	Chemical analyses, % wt						
Pipe size	*C*	*Mn*	*P*	*S*	*Si*	*Cr*	*Mo*
4 in. Sch. 80	0.15	0.46	0.01	0.020	0.53	5.46	0.50
8 in. Sch. 40	0.12	0.46	0.019	0.020	0.35	4.65	0.50
	0.13	0.43	0.020	0.013	0.29	4.57	0.50
8 in. Sch. 80	0.115	0.47	0.014	0.009	0.41	4.88	0.45
12 in. Sch. 80	0.06	0.47	0.016	0.019	0.19	4.44	0.48
	0.09	0.40	0.023	0.019	0.27	4.77	0.46
	0.09	0.49	0.021	0.015	0.28	5.06	0.56
	0.10	0.53	0.023	0.012	0.21	4.59	0.49

Electrodes

In all cases the pipe joints were welded with AWS Class E502–15 electrodes.

Exothermic Material

The exothermic material consists primarily of aluminum powder, metal oxides, refractory materials and binders. It was received in preformed half cylinders, Fig. 1, designed to fit the outside diameter of the pipe joint. The exothermic material resembles a ceramic which has been baked in an oven to give it structural strength. The specific material used, when ignited with an oxyacetylene torch, burns with a delayed exothermic reaction and although its active constituents are consumed, it retains its original geometry.

Prior to welding the joints, thermocouples were located internally, one quarter of an inch from the root of the joint, and at various other points along the inside diameter of the pipe.

The half cylinders of exothermic material were placed over the weld. Insulation was located adjacent to and

on both ends of the exothermic material which was then covered with a high temperature insulation that extended two inches on either end. Following this, a 1/4-in. thick layer of asbestos fiber was secured over the high-temperature insulation. Asbestos cement was used to seal the ends of the joints formed by the insulation. Figure 2 illustrates an approximate longitudinal cross section of the assembly and Fig. 3 shows a complete assembly.

The exothermic material was ignited through two 3- x 2-in. ports located at each end of the high-temperature insulation, 180 deg apart. Subsequent to ignition with an oxyacetylene torch, the four ports were closed with insulation.

After the heat-treating cycle, the entire assembly was left to cool to ambient temperature before removal of the insulation.

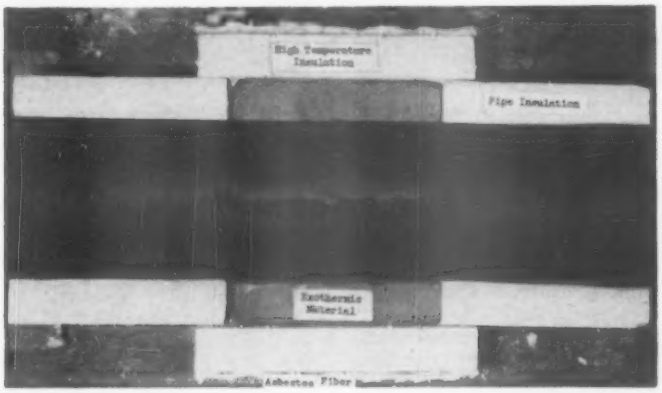

Fig. 2 Cross section of assembly

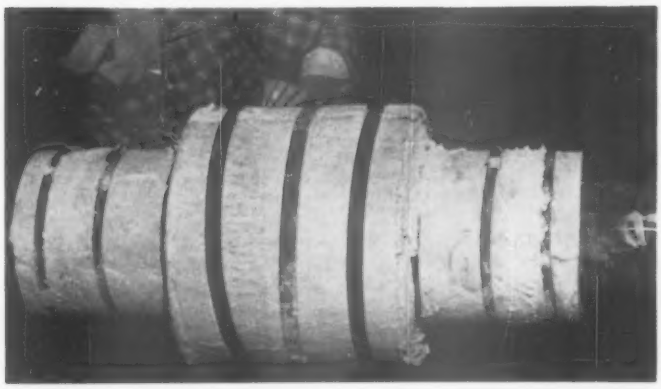

Fig. 3 View of complete assembly

Results and Discussion

Initially, the program was divided into two phases: (1) the application of an exothermic material that yielded subcritical heat-treating temperatures in the steel (about 1350° F), and (2) material that produced annealing temperatures in the steel (1475–1650° F).

After several tests, it became apparent that phase one was not the direction to go because of the inconsistent reduction of the as-welded hardness of 5% Cr–0.5% Mo weldments to within acceptable values. Phase one was therefore discontinued and emphasis was placed upon phase two.

The use of an exothermic material involves a postheat-treating method that departs from presently used procedures; i.e., a relatively slow heating and cooling cycle. Since the heating and cooling cycle of the exothermic material was relatively rapid, it was necessary to determine whether a proper balance between the maximum temperature reached, the time at at maximum temperature and the cooling rate would be obtained.

The maximum temperature, generally above 1500° F, was reached within 15 to 20 min. This rapid heat input had no adverse effect upon the weldments.

With regard to time at temperature, it was found that 2.5 to 6.7 min at maximum temperature was of sufficient duration. The shorter time at maximum temperature was generally balanced by a higher maximum temperature. These factors are "built into" the exothermic material and cannot be completely controlled. Some variations in these factors can be seen in the data, Table 1, and result from the heterogeneity of the mixture used to produce the material. Each batch

Table 1—Postheat Treating Cr-Mo Weldments with an Exothermic Material

Representative Data

Pipe size, (Sch. 80), in.	*Exothermic material cylinder dimensions, in.*	*Wt of exothermic material*	*Insulation: Over exothermic material, in.*	*Insulation: On pipe, each end of exothermic material, in.*	*Max temp, ° F*	*Time at max temp, min*	*Avg. cooling rate, ° F, 1st hour*	*Initial Bhn, (weld)*	*Final Bhn, (weld)*
			Experimental values						
4	1 1/2 x 8	14 lb-14 oz	2 x 12	1 1/4 x 16	1565	2.5	420	388	197
	1 1/2 x 8	14 lb-3 oz	2 x 12	1 1/4 x 16	1480	4.2	410	388	178
8	2 1/4 x 12	57 lb-14 oz	2 x 16	2 1/4 x 16	1550	6.7	240	358	178
	2 1/4 x 12	58 lb-12 oz	2 x 16	2 1/4 x 16	1575	3.3	245	379	168
12	2 1/2 x 18	136 lb-14 oz	2 x 22	2 1/2 x 16	1540	5.0	200	355	147
	2 1/2 x 18	125 lb-12 oz	2 1/2 x 22	2 1/2 x 16	1620	5.8	275	328	132
			Calculated values						
6	1 3/4 x 12	35 lb	2 x 16	1 3/4 x 16					
10	2 1/3 x 15	99 lb	2 x 19	2 1/2 x 16					

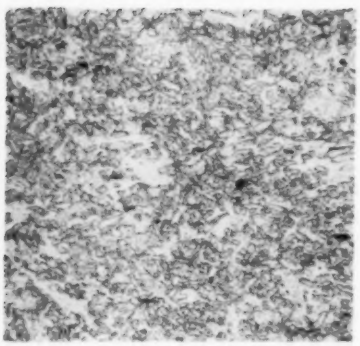

Fig. 4 As-received base metal, X 100

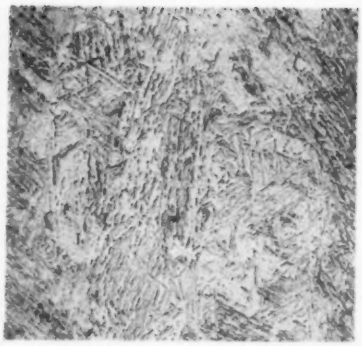

Fig. 5 Weld metal, as-welded condition, X 100

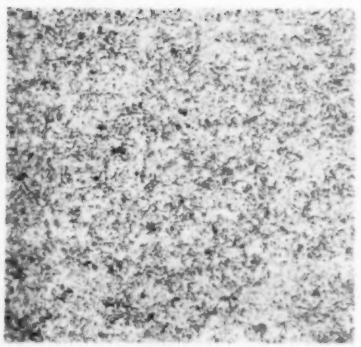

Fig. 6 Heat-affected zone, as-welded specimen, X 100

of exothermic material can be expected to vary because, at the present time, it is a hand-made item. However, the use of mechanized production methods will result in a more uniform product.

Another factor that undoubtedly had considerable effect on final results was the fairly long soaking time of about 2 to 2½ hr as the assembly cooled from maximum temperature to 1000° F.

The cooling rate will be controlled primarily by the kind and amount of insulation used. A high-temperature insulation was found to be necessary to cover the exothermic material to minimize heat losses. The insulation placed on the pipe adjacent to the exothermic material serves to reduce conduction losses and need not be a high-temperature insulating material.

The insulating materials shown in Figure 2 and the dimensions of which are included in Table 1 were found to be entirely satisfactory. It should be emphasized that reproducibility of results depends upon using the insulating materials and dimensions discussed in this paper. Any change in insulation may effect final results.

It was found essential that radiation and conduction heat losses be kept to a practical minimum. Fortunately, radiation losses can be minimized by careful fitting of the exothermic material and insulation. Since the greater losses are through conduction, these were controlled by sufficiently insulating the exothermic material and particularly the pipe adjacent thereto.

This higher-temperature material also allowed for some variations in ambient conditions in the laboratory, particularly as regards moving air. Although still air was the ideally desired condition, in practice, some motion of the air was inescapable. Since heat losses due to moving air were expected, it was proper procedure to seal the ends of the pipe and, if thought desirable, to shield the assembly with screens. Ambient temperature was itself a variable; but for shop heat treating it was considered that ambient temperature would be at the least in the 70° F range.

The specified application of the exothermic material was developed experimentally in the laboratory and its effectiveness in the shop and field has been satisfactorily demonstrated. For example, one experimental test was conducted in the field where the ambient temperature was 34° F with a wind velocity up to 23 mph. The test was conducted with 8 in., Sch. 80, 5% Cr–0.5% Mo pipe, using the same assembly and dimensions as given in Table 1.

The results were quite satisfactory. The initial weld-metal hardness of 358 Brinell was reduced to a maximum of 142 Brinell. The maximum temperature reached was 1570° F and the average cooling rate for the first hour was 240° F. This suggests that the assembly developed can be used down to at least 32° F without requiring additional insulation.

Where lower ambient temperatures are involved, it may be necessary to add additional insulation to that itemized in Table 1.

Because the heating-and-cooling cycle was relatively rapid, a metallographic examination was conducted to determine whether any detrimental effects were evident in the heat-treated 5% Cr–0.5% Mo pipe weldments. Examinations were made of the steel in the as-received, as-welded and postheat-treated conditions.

The as-received base metal, Fig. 4, shows a normal structure of dispersed carbides in a ferritic matrix.

In the as-welded condition, the structure of the weld metal, Fig. 5, was martensitic. The heat-affected zone, Fig. 6, adjacent to the weld metal showed an unresolved martensitic matrix containing dispersed carbides.

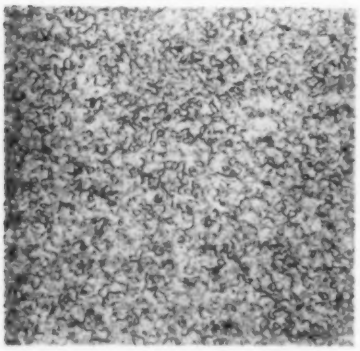

Fig. 7 Base metal, heat-treated condition, X 100

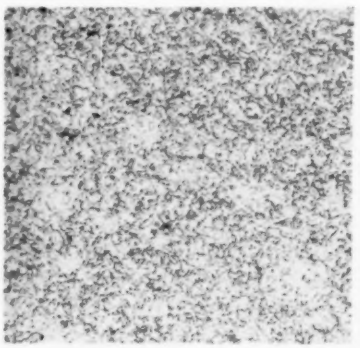

Fig. 8 Heat-treated weld metal, X 100

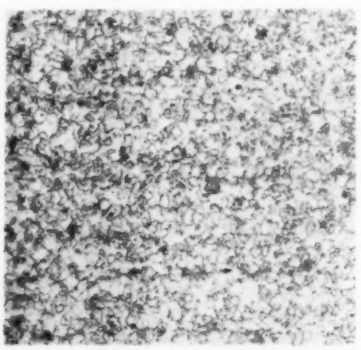

Fig. 9 Heat-treated heat-affected zone, X 100

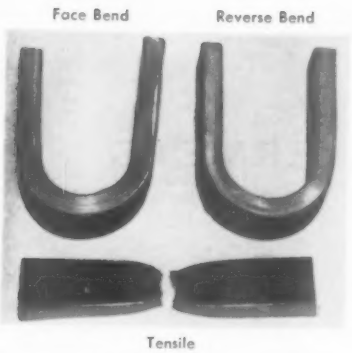

Fig. 10 Specimens from unaffected base metal

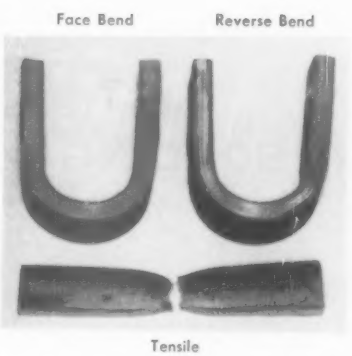

Fig. 11 Specimens from exothermic material-pipe insulation interface

Fig. 12 Specimens from postheat-treated welded joint

The structures in the heat-treated condition of the base metal, the weld metal and what was the heat-affected zone are shown in Figs. 7 to 9, respectively. Other than reduced grain size, the structure of the heat-treated metal is comparable to that of the as-received material; a ferritic matric containing dispersed carbides. The solid black areas are voids that, prior to etching, contained inclusions.

As regards the Cr-Mo steels, it is generally known that retained austenite can transform to martensite below 600° F. Since the assembly was permitted to cool to ambient temperature before removing the insulation, the continuous cooling rate was slow enough to allow any retained austenite to transform to a ferritic structure. Metallurgical examinations substantiated this as no islands of martensite, representing prior austenite, were in evidence in the postheat-treated specimens. The metallographic examinations indicate that the use of an exothermic material as a postheat-treating medium with regard to the 5% Cr–0.5% Mo steels does not have a detrimental effect upon the weldment.

To supplement the metallographic examinations, mechanical property tests were conducted on sections cut from the heat-treated pipe. Tensile, face and reverse-bend specimens were taken from the juncture of the heated band and adjacent area (steel at exothermic material-pipe insulation interface) and transverse specimens cut through the weld. As shown in Figs. 10 to 12, all guided-bend specimens, face and reverse, were bent through 180 deg without failure. The tensile specimens, in all cases, developed the required tensile values and showed ductile fractures.

Representative data obtained are tabulated in Table 1. Included are the dimensions of the exothermic material used, the high-temperature insulation, and the pipe insulation required to postheat treat 5% Cr–0.5% Mo wrought pipe weldments. Calculated values are given for 6 in. and 10 in. Sch. 80 pipe sizes.

Considerably more work was involved than is shown in Table 1. In the interest of brevity, this table was designed primarily to indicate the physical arrangement that was found to be satisfactory and, when duplicated, will ensure reproducibility.

The simplicity of application of this postheat-treating method will result in cost savings as fewer and relatively unskilled personnel can apply the material. Over-all construction costs will be reduced as any number of joints can be postheat treated simultaneously.

Another facet of the program was an attempt to establish a simple mathematical relationship between the materials used and the various pipe sizes. This aspect of the program is still being developed.

As a final note, the application of an exothermic material as a postheat-treating medium has been developed. However, it should be emphasized that considerably more work will be necessary to develop fully its applications as well as to ascertain its limitations.

It is hoped that through this paper, interest will be stimulated to the extent that others will investigate the potential of using an exothermic material as a postheat-treating medium.

Conclusions

The data obtained to date and actual shop and field applications indicate that 5% Cr–0.5% Mo wrought pipe weldments can be successfully postheat treated with an exothermic material.

Metallurgical examinations and physical tests show that no detrimental effects are incurred by the weldment through this method of postheat treating.

This simplified method of postheat treating will result in cost savings, particularly as regards field applications.

Acknowledgment

The authors express their thanks to Exomet, Inc., Conneaut, Ohio, for supplying the exothermic material and pipe insulation used in the program.

Acknowledgment is made to S. F. Herbster for his invaluable assistance with the laboratory work and to R. R. Hayward for the metallographic contributions.

INSTRUCTIONS

FOR

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A SURVEY OF THE BONDING OF CERMETS TO METALS

Metallizing history, joint design, joint materials, methods of wetting, methods of increasing braze strength and other pertinent topics are reviewed in this literature survey

BY G. R. VAN HOUTEN

ABSTRACT. Brazing cermets to metals is complicated by the great differences in thermal coefficients of expansion and by the difficulty in finding braze metals which will wet cermet surfaces. The need for brazes which are strong at high temperatures (and therefore melt at even higher temperatures) further increases the problem of differential expansion.

This literature survey reviews metallizing history, joint design, joint materials, methods of wetting, methods of increasing braze strength, methods of correcting for differential expansion and other topics pertinent to the production of a strong high-temperature braze for cermets.

I. THE PROBLEM

Almost every technical literature review is initiated because of interest in a specific problem. Even though the title may imply broad coverage, a survey initiated to answer a question inevitably exhibits selective emphasis. The reader should be advised on the problem-behind-the-search so that he himself may judge whether coverage of each area is likely to be sufficiently comprehensive.

The problem behind this literature search was the need to join a fairly large cermet insert to the main metallic body. The design prohibited a mechanical seal. The joint was required to be vapor tight and to withstand compressive shock as well as compressive and tensile stresses at very high temperatures. The braze was to be corrosion resistant (including resistance to stress corrosion) and the completed assembly was to exhibit dimensional stability. The cermet to be used was a nickel-bonded titanium carbide.

For the problem at hand, the literature on joining cemented carbide tool tips to tool shanks promised to be of greatest interest. However, because of the severe temperature demands placed on the system, most of the conventional brazing materials and procedures were unsuited. Therefore, a review of the entire field of ceramic-to-metal bonding was necessary.

G. R. Van Houten is Associate Laboratory Director for Chemical & Metallurgical Research, Corporate Laboratories, P. R. Mallory & Co., Inc.

II. HISTORY

The history of ceramic-to-metal seals (Fig. 1 illustrates a typical assembly) is a very long one. Some ancient samples of earthen ware are reddish, while other samples, from the same clays, are black. The difference between the two lies in the way each was fired. The clays contained iron compounds. When the firing atmosphere was oxidizing, the fired ware came out a light brown-red. When the firing atmosphere was reducing, the result was a black fired-ware.* In general, a part of the iron content was merely altered to a lower oxide, e.g., magnetite, but in at least a few cases, some of the oxide was actually converted to metallic iron.

Ceramic ware decorated with films or glazes containing metallic oxides (particularly those of copper and iron) has been known for thousands of years. In a few of these ancient glazes, at least a portion of the oxides have been converted to metallic particles.

The oldest known ceramic ware decorated with metallic films is the "lustre" ware of the Near East.[62] Lustre ware was made by painting a copper-base or silver-base metallic salt on glazed ware and then heating it at a low temperature "in a special kind of kiln" (undoubtedly one with a reducing atmosphere). This produced an adherent metallic film on the surface of the ware. If the film was thin enough, it appeared to be iridescent.

It was not until the early 1700's that the practice of metallizing ceramics for decorative purposes became popular in the Western World. At first the gold and silver trim was merely applied in sizing and was not fired. Then, probably due in great part to W. H. Wollaston's commercialization of the platinum metals and his general development of powder metallurgy procedures, it also became the custom to use platinum and to fire on the precious metal trim. The procedure developed then is still in use. The metal powder is mixed with a small amount of flux or fusible ground glass. The ceramic is coated with a slip of this mix and is then fired. This procedure is much like the procedure used to enamel metals.

* See *Encyclopedia Britannica*, "Primitive Pottery."

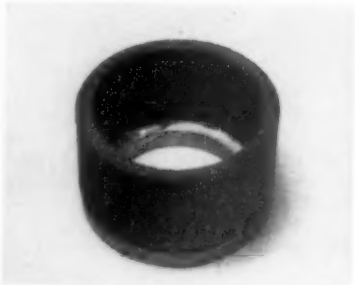

Fig. 1 Alumina cylinder bonded to tungsten-base ring

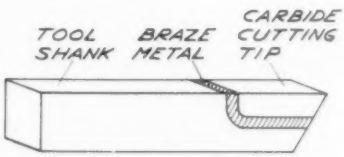

Fig. 2 Typical carbide-tip cutting tool

The advent of the electric light bulb created the first great interest in gas-tight glass-to-metal seals, a rather specialized problem in ceramic-to-metal bonding. The recent use of high-temperature ceramics in place of glass has led to renewed interest in high-temperature hermetic seals.

World War II led to the mass acceptance of cemented carbides as cutting tools (see Fig. 2). The 1927–36 decennial index of *Chemical Abstracts* included only three references to the joining of metals to ceramics, but the

1937–46 decennial index contained 66 references to metal-ceramic joints, under the headings of electronic valves and cemented carbides.

The foregoing is a brief history of the joining of metals and ceramics prior to 1947. Activity in the following decade (1947–56) continued at an even more rapid pace.

The past twelve years have seen the development of three new sealing techniques (Mo-Mn, TiH and active metals) that now dominate the field of ceramic-to-metal seals. The past twelve years have also seen the development of a great number of new cemented refractories now lumped together in a category called "cermets."

It is this mass of history and literature that the writer will attempt to review.

It might be well to list several key reference sources and topic headings which should be of interest to anyone conducting a similar investigation: Ceramic Abstracts, British Ceramic Abstracts, *Chemical Abstracts* (ACS), Crerar Library Abstracts, Engineering Index, Industrial Arts Index, Metallurgical Abstracts (Institute of Metals—London), Metal Powder Reports (London) and Review of Metal Literature (ASM).

The *ASM Review* conveniently lists most pertinent references in section K (welding and joining) under subheadings K-8 (brazing) and K-11 (joining of nonmetals) but the abstracts are so incomplete that usually little benefit accrues unless the original article is consulted. In any of the abstracts, pertinent references may be found under any of the following headings: Brazing, Cemented Carbides, Ceramics, Ceramic to Metal Seals, Cermets, Coatings, Coefficient of Thermal Expansion, Electronic Valves, Glass to Metal Seals, Hard Alloys, Hard Metals, High Temperature Materials, Interfacial Tension, Jet Engines, Joining, Joints, Metallurgy (of refractory metals), Metals, Powder Metallurgy, Refractory Alloys, Sealing, Seals, Soldering, Titanium Carbides, Tungsten Carbides, Vacuum Tubes, Welding and Joining and Wettability.

III. THE REVIEW

Review of the references examined will be divided into seven parts:

A. Cermets.
B. Filler materials for cermet-to-metal brazing.
C. General brazing procedures.
D. Procedures for brazing cemented carbides.
E. Special brazing procedures.
F. Use of Mo-Mn, active metals and active metal-hydrides processes in metal-to-cermet bonding.
G. Physical testing of brazes.

A. Cermets

1. DEFINITION OF A CERMET

The term "cermet" did not come into accepted use in the United States until 1948. It has still not received complete acceptance in England and as yet has no standard definition. Schwartz[137] gives the term "cermet" a wide meaning with four subclasses:

(*a*) Oxide base cermets (e.g., Cr-Al_2O_3).
(*b*) Carbide base cermets (e.g., Ni-TiC).
(*c*) Boride base cermets.
(*d*) Intermetallic base cermets (e.g., 70% $MoSi_2$, 30% Al_2O_3 - CaO).

Schwarzkopf and Leszynski[138] describe cermets as including the cemented hard metals and oxides, whatever their high-temperature properties.

Two reviews which list the chief materials considered to fall under the category of cermets, together with the conditions of formation,[12, 75] state that components should show similarities in crystal structure, in atomic and ionic radii and in type of chemical bond. A direct chemical bond of a metal with a ceramic oxide (except that of the same metal) is very difficult to achieve because of the differences in atomic radii. (The exceptions to this are the metals of low atomic number, e.g., Al, Mg, Be and B.)[65] Therefore, binders such as carbides and nitrides are sometimes used since their crystal structure and atomic radii are similar to those of the ceramic oxides. It should be remembered in discussing cermets that the classic definition of ceramics has now been expanded to include carbides, nitrides, silicides, borides, aluminides, titanides, etc., as well as the oxides of the older connotation.[126]

2. EVOLUTION OF THE CERMETS

One of the most widely known individuals among the developers of sintered carbides is W. Dawihl.[30, 31] B.I.O.S.* Report No. 925[19] describes Dawihl as the man who did "all the carbide research for Krupps."

Skaupy,[142] however, would appear to be the rightful father of today's cermets since he directed the research that led to the development of the commercial cemented tungsten carbides of the 1920's.[72]

A brief but exceptionally good picture of the inception of the carbides is to be found in Smithells' book[143] (pp. 290–291). Smithells calls attention to the original German patents of Voigtlander and Lohmann (filed in 1914) covering tungsten carbide[156] and cemented tungsten carbide.[157] Smithells also calls attention to the 15 patents

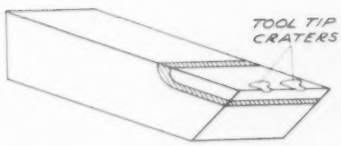

Fig. 3 Carbide tip craters

which led to the manufacturing techniques in use today. An excellent and very comprehensive survey of the cemented carbides, from conception to the then current practices (1949), may be found in Goetzel[48] (pp. 75–170).

3. PROPERTIES OF CERMETS

a. General Properties of Cermets

The tremendous number of cemented carbide patents comes in part from the fact that each slight change in carbide or binder composition *or ratio* produces marked changes in the performance of a carbide cutting tool. As a consequence, each carbide manufacturer offers a large number of grades, all identified by the manufacturer's own code number.

Numerous efforts were made to catalog the various U. S. trade names and numbers as well as their specific compositions, together with the manufacturer's specific recommendations for use.[48, 134] It was not until the 1950's, however, that 14 types of cutting-tool carbides were agreed upon as being most commonly used and these types given the standard designations C-1 to C-14. A list of these grades, together with a tabulation of the trade names of the materials which fall into each class, may be found in an article by Monacelli.†[108] These grades cover a wide range of hardness, toughness and brazeability.

In general, the greater the amount of binder, the easier the carbide is to braze. The carbide with a higher percentage of binder is tougher and has better impact resistance, but it is also softer. This means higher tool wear. The relative importance of wear and fracture rates varies, of course, with the nature of the work to be done.

One type of tool wear, cratering (see Fig. 3), is reduced if the cutting tool contains a relatively high percentage of titanium carbide. A list of Schwarzkopf's original patents on this subject may be found in Goetzel.[48]

The addition of titanium makes the carbide considerably harder to "wet" and further reduces the number of suitable binders and braze materials. In general, all the carbide additives tend to complicate the problems of bonding and brazing tungsten carbide. The development of the

*B.I.O.S.—The British Intelligence teams which entered Germany during and immediately after World War II to gather up technical information before it was permanently "lost."

†A recent (March 1956) British article catalogs Russian and German systems for grading carbides.[106]

cemented all-titanium carbides has still further increased binding and brazing problems.

b. *Wettability of Cermets*

Almost all ceramics are hard to "wet" as is evidenced by their use in brazing fixtures.[140, 167] This difficulty in wetting ceramics is also put to use when surfaces of porous tungsten skeletons must be kept free from surplus infiltrant.†

In machining, point-of-contact temperatures are often extremely high. Sticking (i.e., welding) of the machined metal to the tool is not wanted since subsequent chips may crowd against "stuck" chip and put an area of carbide under tension, thereby causing cratering. Therefore, wetting and the consequent welding are not desirable.* Except for a few cases, such as the two just described, i.e., brazing fixtures and cutting surfaces, an improvement rather than a reduction in wettability is sought.

The search for metals which would wet titanium carbide‡ has been quite extensive [10, 39, 55, 124, 126] particularly at MIT.[38, 64, 77, 78] Of all the materials tested to date, only nickel and cobalt appear to produce extensive bonding. Engel states that chromium and titanium will also adhere to a porous titanium-carbide cup (made from five micron powder) after being cooled below their melting points, but that, "the penetration indicates that they do not surround the TiC particles as thoroughly as does nickel or cobalt."[39] Richardson also suggests the addition of Mo, Al or Cr to the Ni binder "to improve thermal shock properties."[126] Humenik and Kingery offer the general rule that wettability and work of adhesion are increased by low surface tension, by interfacial reactions and by high metal-oxide bond strength.[64]

With this brief picture of the cermet materials to be wet, we shall proceed to the materials used as brazes and, later, to the techniques used to make these braze materials effective.

B. Filler Materials for Cermet-to-Metal Brazing

1. CONVENTIONAL MATERIALS

The number of commercially available brazing alloy compositions is in the hundreds. One of the best brazing alloy lists available to date is found in ATI-161972 (UNCL)[168] compiled by Banks, Bredzs and Parks (Armour Foundation) in 1952. This compilation lists more than two hundred low and intermediate temperature brazes (1100° C), complete with trade names and compositions. A more comprehensive list was recently compiled by Reber and is being currently revised by Goldman, under the direction of Patriarca, ORNL Welding Division. The list now has about five hundred entries. This new compilation is based on ten previous compilations in addition to direct correspondence with the more than 30 primary manufacturers of brazing materials.

The emphasis of this and other lists, however, has been on materials for conventional metal-to-metal brazing. As stated earlier, many of these standard commercial brazes have not proved satisfactory as cermet-to-metal brazes.

2. ZINC-RICH AND COPPER-RICH BRAZE MATERIALS

The AWS Brazing Manual states that: "Although any of the BAg 1 through BAg 7 filler metals may be used (to braze carbides), those which contain nickel (BAg 3 and BAg 4) are generally preferred because nickel improves wettability. BCuZn6, BCuZn7, BCu and BAgMn are also widely used (and the first two are particularly recommended) where a postbraze heat treatment is required."[78] Bogen generally concurs on the use of zinc-rich brazes, stating that copper, yellow brasses and silver solders may be used for brazing tungsten-carbide tool tips to chromium-bearing drill-rod steel, but that white-spelter solders (e.g., Cu 46.5%, Zn 42.5%, Ni 10.5%, Sn 0.1%) are much more satisfactory.[13]

A German patent[2] describes a brazing powder for carbides made by melting a high-copper brass (81% Cu, 1% Ni, 0.6% Ag, balance Zn) with up to 30% iron. (It is claimed that after brazing, the iron is found to be uniformly distributed in the braze area.) A French patent,[10] also based on a brass (i.e., Cu-Zn) brazing powder, suggests that it be mixed with borax and powdered glass. (Iron is substituted for the brass powder and calcium disilicide for the glass if high-speed steel tips are to be brazed on in place of carbide tips.)[9] One of the more complex zinc-bearing brazes consists of silver (50%), cadmium (16%), copper (15.5%), zinc (15.5%) and nickel (3%).[44]

It has been claimed that the presence of the zinc in brazes improves the ability of the braze to wet the cermet, e.g., in one case the zinc is mixed with a high melting-point material with which it does not alloy. The zinc vapor, which is evolved first, is said to make the ceramic much easier to wet.[151] In the reverse case, where a protective ceramic coating is to be applied to a metal, the presence of zinc is not desirable. The reason is explained by King, "If an alloy, e.g., high-zinc brass, contains an element with a high vapor pressure at elevated temperatures, a good bond is practically impossible (because of the continued evolution of metal vapor at the interface)."[76]

Brooker and Beatson[23] compare the use of copper, silver[27] and 60/40 brasses as follows: "Pure silver is seldom used as an industrial braze except for brazing nickel-iron attachments to ceramic bodies on which the joint areas had previously been metallized with iron or cobalt."** In a discussion by the same authors as to choosing between copper and 60/40 brass for brazing carbides, the following points are emphasized:

Copper:

(*a*) wets carbides fairly well;
(*b*) makes good thin joints for percussion or high pressure applications;
(*c*) has good strength at moderately elevated temperatures;

but copper requires a brazing temperature of 1100° C, and so:

(*d*) the use of torch brazing is almost impossible;
(*e*) tool shanks are thoroughly annealed (undesirable when special shank properties are sought);
(*f*) much stress is induced because of the large ΔT (braze temperature minus use temperature) $\times$ Δ coefficient of expansion (metal coefficient minus cermet coefficient) product; further,
(*g*) there is a tendency toward formation of voids when copper is used with thickening inserts.

(Items "f" and "g" will be discussed in detail in the next section, General Brazing Procedure.)

In the early 1940's, Balke and Haskell each patented silver-copper-nickel-manganese brazing alloys containing "little or no cadmium or zinc." In 1941, a French patent was also granted for copper-cobalt and copper-cobalt-manganese brazing alloys.[26] About this same time, powdered forms of several copper and silver-copper brazes for carbides were made available. One German patent of the mid-1940's claims excellent results when a 70–75% Cu, 23–28.5% Ni, 1.5–2% Mn (melting point 1250° C) is used for brazing carbides.[128] A patent of a few years later covers the use of Monel metal (67% Ni, 30% Cu, 2% Fe, 1% Mn) for a similar application.[111] As-yet-unpublished work at ORNL and a recent (June 25, 1956) article[146] in-

† Surfaces to be kept clean are coated with calcium oxide (CaO) prior to immersion in the copper infiltrant.

* With this behavior in mind, Dawihl ran a series of temperature of adhesion tests to determine the temperatures above which tungsten, tungsten carbide, titanium carbide, cobalt and their alloys would stick to steel and to each other.[19, 20, 21] (The values ranged from a low of 500° C, for soft steel vs. cobalt to a high of 1175° C for titanium carbide vs. hard steel.)

‡ McPherson and Hansen[99] have compiled 18 binary phase diagrams for titanium (including Ti-C) to gether with a list of 97 references.

** A 1951 reference claims that silver is the only successful binder for $MoSi_2$.[102]

dicate that the Cu or Cu-Ni brazing alloys containing phosphorus should be used with caution since the phosphorus may form brittle nickel phosphides.

3. MISCELLANEOUS BRAZE MATERIALS

Tungsten carbide coated successively with layers of copper and silver (1946)[37] and tungsten carbide coated with nickel-silver (17–32% Zn, 10–30% Ni, balance Cu) (1952) are among the more exotic brazing materials for carbides.[161] These are especially recommended for bonded diamond tools to be used for very abrasive deposits. In the early 1930's the Russians reported on the relative performance of carbide bits brazed with copper, an iron-tungsten carbide, an iron-molybdenum bonded tungsten monocarbide and copper plus the monocarbide.[80, 155] (The iron-tungsten carbide was reported as holding up better for drilling, with both carbide-rich brazes giving better service "if the braze temperatures were low enough for them to keep their toughness.") Excepting the copper, all these brazes have the very desirable quality of matching the coefficient of expansion of the carbide tip (the importance of this fact will be discussed in detail in the following section, General Brazing Procedures).

One method of manufacturing diamond-drill crowns utilizes hot pressing to sinter a mixture of binder powders to one another and to a steel shaft insert.[82] The composition of these powders is: (*a*) cobalt (4.2%) bonded carbide (WC, TiC, Mo_2C, etc.) powder (70%), plus (*b*) nickel + nickel-beryllium powder (19.5%) plus (*c*) manganese powder (7.5%) and plus (*d*) copper powder (3%). Powder (a) is added to the previously mixed powders (b), (c) and (d) for a final mixing. Diamond tools, both with and without the addition of carbides, may be bonded with 30–60% Co, 8–28% Sn, balance Cu (hot pressed at 750° C)[110] or with 30–50% Co, 25% Cu, 20% Ag, 10% Sn (in which the cobalt may be wholly or partly replaced with nickel and/or iron) or with 80% Cu, 10% Sn, 10% Pb.[37] Another Russian article (1945) reports a test in which the best brazing results were obtained with a ferro-manganese brazing alloy containing 20-25% copper.

One class of bonding agents, the metalloids, has received relatively little comment. Kingery is one of the few to refer to this class of materials[77] (1953). A 1937 patent describes the use of aluminum arsenate as a binder,[145] and a 1938 patent describes a brittle alloy containing iron group metals (40%) with iron-group (or Mo, W or Cu) phosphides or arsenates as the binder.[118] Silicon, tantalum, titanium, zirconium and boron additions are also described.

Pb (18%)–In (12%)–Sn (70%) is a low temperature solder.[14] Since most cutting tools occasionally heat up during use, neither this nor the organic adhesives[27, 73, 74] are normally suitable as bonding agents.

As a final word concerning materials, anyone who seeks possible cermet braze alloys among the materials used as binders for grinding wheels, should do so with caution. Gardner and Lister state the potential danger very well in their patent application for Wickman, Ltd.[162] "The bonding material used in grinding wheels should be uniformly brittle to permit release of the abrasive particles when they become dulled by wear." In some cases, a controlled degree of brittleness can be an asset, but possible complications arising therefrom should not be overlooked.

C. General Brazing Procedures

1. THE PROBLEM—WETTABILITY

It might be well to review the problems and the techniques employed in conventional brazing operations before discussing the techniques for metal-to-cermet brazing in detail.* The basic problem of brazing is a matter of causing a liquid metal or metals to wet the surface of similar or dissimilar solid metals (either with or without alloying). Brooker and Beatson[23] describe the phenomenon of wetting quite simply. "The solid is wetted by the liquid if a film of the liquid refuses to drain away when a force such as gravity causes the bulk of the liquid to flow off the solid surface."

Many patents and authors have called attention to the merits of alloying, but wetting alone is quite enough to produce a good bond. Brooker and Beatson[23] (p. 21) describe work on wetting, stating that "in all cases where the surface was wet while the braze (a Sn-Pb solder) was molten, the forces of attraction after solidification were very great and were comparable in magnitude with the cohesive forces existing in the body of a solid metallic mass." In what appears to be an excellent experimental study of pure wetting (together with biaxial constraint and other phenomena), Bredzs[17] (1954) was able to obtain silver-to-iron braze strengths in excess of 84,000 psi. This, together with other experimental evidence with which the writer is familiar, e.g., the strength of copper impregnated tungsten, should be quite enough to testify to the bond strengths possible with pure wetting.

* Probably the best, though not always the most theoretically inclined, coverage of this subject is to be found in the book by Brooker and Beatson (1953).[23] This book contains a wealth of illustrations and "this-is-how-we-do-it" details.

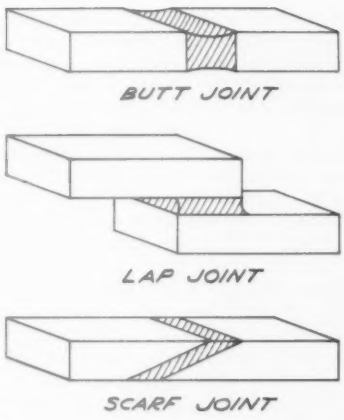

Fig. 4 Braze joint design

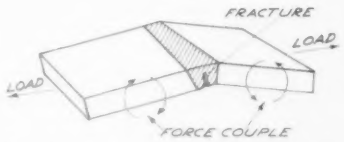

Fig. 5 Joint failure due to misalignment

Stable oxides and carbon are normally very effective barriers to wetting. At lower brazing temperatures these oxides are removed with fluxes. At higher brazing temperatures, e.g., copper brazing temperature, the use of a reducing atmosphere, such as hydrogen or dissociated ammonia, usually assures that oxides will not form on or will be removed from the surfaces to be brazed.

2. JOINT DESIGN

Braze joints normally fall into one of three classes: lap, butt or scarf (see Fig. 4).

The lap joint is preferred for several reasons. First, the load is spread over a much larger braze area. Second, the problems associated with minor misalignment or with voids and bubbles are of lesser consequence in shear loading.

The butt joint which is sometimes required for design or appearance reasons usually results in putting the whole load on a very small braze area. Further, bubbles and voids in the braze area can serve as stress raisers, putting as much as three times the normal stress on immediately adjacent braze areas.

Braze yield strength and brittleness further complicate the alignment problem. If there is misalignment, some area of the braze is usually stressed disproportionately (see Fig. 5). In this case, either local rupture or local yielding must occur. Depending on

the relative properties of braze and base materials, the rupture or tear may occur in one or the other or at the interface. If yielding occurs, either the overstressed braze area or the main body of metal must yield until the alignment changes sufficiently to redistribute the load. Ruptures are usually catastrophic. After each failure, the load on the remaining area becomes even greater, for unless alignment is achieved (by reason of at least limited ductility), there is actually a lever action on some part of the braze.

The scarf joint is actually an attempt to combine the neatness of a butt joint with the strength of the large-area lap joint. Joint preparation and jigging are much more difficult than for the other two types.

In all three cases, the braze filler metal may be so placed (or preplaced) as to take full advantage of the specific capillarity of the braze-base combination. This technique is important in that it can help reduce the number of large bubbles and voids in the braze.

Brooker and Beatson (p. 154) review the problem of joint design in detail and list eight rules for good joints.[23]

1. Design joints to be in shear. Avoid butt joints.
2. Make the shear surface parallel (except if of aluminum).
3. Make the minimum shear length at least three times the thickness of the thinner member being joined.
4. Make the parts to be joined self jigging—avoid separate jigs.
5. Make the cross sections of the two parts approximately equal, to aid even heating and therefore more uniform distribution of stress.
6. (Except for Cu brazes) Use chamfered corners at the beginning or end of a capillary path but never in between.
7. Arrange the pieces so that gravity as well as capillarity helps the brazing material to fill the joint.
8. Do not depend on flow of the braze further than $^5/_8$ in. from the point of application (less with aluminum base parts).

This list does not mention the very important matter of gap clearance just prior to brazing. Optimum clearance for effective wetting is normally an inverse function of the surface tension-fluidity product, e.g., for a braze material such as copper, which has a low viscosity and generally high capillarity, an interference fit prior to infiltration may yield the best joint. To make proper use of capillarity, a copper-brazed joint should have a "while-brazing" clearance of 0.003 in. or less. (A 1956 article sets this maximum clearance at 0.001 in.)[149] For most other brazes the *minimum* "while-brazing" clearance is 0.001 in.

If the braze-metal alloys with the adjacent surface, the resultant change in braze composition usually increases its viscosity. Therefore, the minimum gap size must be increased in order to avoid premature stoppage of the flowing braze metal. If, in addition to alloying with the adjacent surface, the braze has a wide plastic range (i.e., if the liquidus and solidus temperatures are far apart), a number of different braze compositions may coexist and there is risk of intergranular penetration.* An example of this is the brazing of stressed Co-Ni-Fe to copper with a silver-copper eutectic braze metal.[23] In this case, the results are much like those of braze-caused stress-corrosion cracking. Stress-corrosion cracking is also a problem in brazing stainless steels or nickel or nickel-base alloys with a low-melting braze.[23]

3. JOINT STRENGTH

The best work to date regarding the effect of braze thickness† on braze strength is that of Bredzs,[17] based on the theoretical analysis of biaxial constraints by Orowan[114–116] (1945–52). Orowan's work showed that if a (ring) notch of proper design were placed around a homogeneous rod, the biaxial constraint thus introduced would raise the loading before failure to three times the normal shear strength of the material. Bredzs showed that if the braze were thin enough, the plastic constraint exerted by the base metals would be sufficient to make the braze strengths proportional to the strength of these base metals, right up to the "brittle" strength (i.e., the strength in pure hydrostatic tension) of the braze metal. Bredzs indicated the extent to which constraint by the base metal may increase the performance of the braze metal, by raising the constraint factor for a silver braze from its normal value of three to a value of 11 (i.e., a braze rupture strength equal to 11 times the normal shear strength of the silver).

In addition to the matter of plastic constraint and effective wetting, variations in braze thickness also change the percentage of voids in the joints. Considering the joint to be a small casting,[23] the greater its volume the larger the shrinkage cavities.

* Such braze materials should be used where time at temperature is short (e.g., torch or induction brazing) if braze properties are to be reproducible.

† See also Reference 55.

‡ Copper and other soft shims tend to fatigue more quickly than most brazes.[132]

4. JOINT SOUNDNESS

The matter of joint soundness is not a function of wetting and gap alone. In addition to unwetted areas and shrinkage cavities, there is entrapped flux (by reason of an increase in viscosity when the flux is saturated with oxides) and gas cavities.[23] The gas is present by reason of local entrapment or generation or by reason of changes in solubility with temperature, and then remains by reason of local surface-tension conditions.

The writer is familiar with production operations in which joint soundness varies from 50 to 100%, depending on the system. Brooker and Beatson catalog braze composition vs. joint soundness as follows:[23]

Typical Braze Soundness
Low-temperature silver brazes
70% (min)–85% (max)
Cu on mild steel in reducing atmospheres (i.e., no flux)—Better than with silver brazes
Brasses (on a variety of base metals)
Poorer than with silver brazes
Aluminum braze joints
Soundness is a function of joint type
(*a*) Line or fillet joint
Good (i.e., matches Ag braze soundness)
(*b*) Pure lap joint
Poor

Based on these figures, typical production joint strengths may be considered to vary from 50 to 100% of the as-cast strength of the braze metal. As mentioned earlier, it is possible to get much stronger joints by utilizing the effects of plastic constraint; however, this author tends to agree with Brooker and Beatson that, except for a very few systems, such high strengths cannot be expected routinely on a production basis.

5. GENERAL CONSIDERATIONS

If the joint is properly designed, if the braze and brazing techniques are correctly chosen and if the resultant joint is sound, the joint will also be fatigue and corrosion resistant,‡[23] and will have good strength at elevated temperatures. It should be remembered, though, that while most braze materials are ductile at elevated temperatures as well as at room temperature, some exhibit "hot shortness." If stressed while in the "hot short" temperature range, these materials may rupture after very little deformation.

The basic properties of a good braze metal, with respect to wetting, viscosity, melting point and boiling point, homogeneity and stability, strength and ductility are tabulated in a number of references.[8, 23, 81, 87] While there is some variation (as a result of differences in emphasis on braze characteristics sought), all lists show gen-

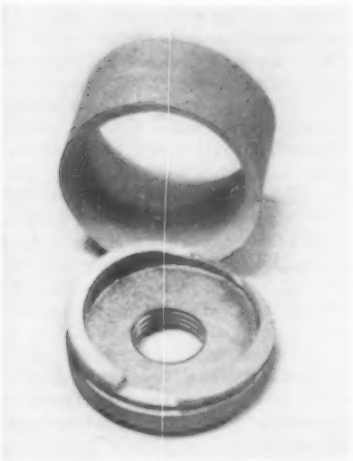

Fig. 6 Failure caused by mis-matched coefficients of expansion

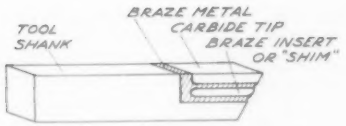

Fig. 7 Carbide tool braze insert

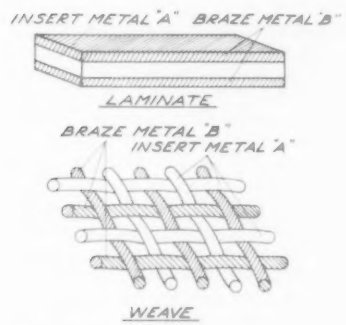

Fig. 8 Braze "sandwiches"

eral agreement and some are almost identical.

D. Procedures for Brazing Cemented Carbides

1. PROBLEMS PECULIAR TO CARBIDE BRAZING

As discussed in the section on Characteristics of Carbides, most carbides are hard to wet and many are rather brittle. In addition, the linear thermal coefficient of expansion of the average carbide is usually about one half that of the adjoined metal. As a result, when a high melting braze is used and the joint is then cooled to room temperature, the difference in the free linear shrinkages of the carbide and the metal may exceed 1%. Based on Young's modulus of Inconel, absorbing a 1% dimensional change can mean that the local stresses exceed 100,000 psi. Parasitic stresses of this type, whether in organic or nonmetallic electrodeposited coatings or in brazes, can lead to premature failure of the base material, particularly when it is as brittle as a carbide (see Fig. 6). As a matter of fact, rapid cooling of many commercial carbide brazes can lead to rupture of the carbide even before use.

2. SOLUTION OF CARBIDE BRAZING PROBLEMS

a. Elimination of Brazed Joints

All these problems are in addition to the regular metal-to-metal brazing problems. Because of such brazing problems, many users have switched to mechanically held tools. Between 1950 and 1955, the sale of mechanical tools increased tenfold,[1] i.e., it increased more rapidly than the sale of brazed tools. One survey in 1952 stated that "some major carbide users maintain it is impossible to braze carbides to metals such as steel and copper successfully."[168] Rose, in 1949, stated that mechanical holding was better for heavy duty because brazed joints were stressed and broke more easily in use, cracked easily and, frequently, were poorly bonded and, further, that replacement of brazed-on tips was harder.[129] Stocker states (re: carbide dies), "high compacting pressures will at times break down an apparently perfect braze joint. The best results have been achieved by eliminating brazing entirely."[150] At least one patent for carbide rock drill bits is based on mechanical holding.[5]

The harder the material is to wet, the more common mechanical holding becomes. Redmond and Graham stated, "...(metal bonded TiC) can be brazed when required but mechanical joints are preferred."[124] A 1954 Russian article described mechanical holding of modified alundum, Al_2O_3, tips which took one centimeter cuts on cast iron.[83] A 1955 article described the mechanical holding of a (neutral) glass bonded alumina because "limited efforts at brazing to steel yielded an unsatisfactory joint."[74] Another report states that at least one manufacturer has been successful in bonding an oxide tip to a steel although "ordinarily ceramic bits are clamped in a holder."[73]*

b. Use of Thick Braze Joints

Despite references to the contrary, carbides *can* be brazed to steels satisfactorily. Many techniques are used, e.g., brazing at the lowest temperature possible to reduce the amount of differential contraction, or brazing with very ductile braze metals, e.g., silver, copper and nickel. The most popular way is to combine the use of a ductile braze metal with increased braze thickness. At least 21 references and patents refer to the use of shims (see Fig. 7) and another 17 to build up of the braze metal by electroplating. As mentioned earlier, the thicker the braze, the less its strength; however, both shims and electrodeposits tend to correct this weakness.

(1) Sandwich Braze (see Fig. 8)

(*a*) *Evolution of the Sandwich Braze.* The evolution of tool-tip braze design can be traced from the early 1930's. A British patent granted in 1936 describes the union of bodies having different coefficients of expansion by welding each body to a metal member having substantially the same coefficient and then joining these two metal members by any suitable means. The method is intended particularly for joining bodies of glass, quartz or other ceramics.[4]

Three German patents of 1939 describe wrapping "hard metal" with a wire mesh or perforated sheet with a higher melting point than the carrier metal. After sintering, the carbide is firmly bonded to the base, which may be of multiple metals.[107]

A U. S. patent granted in 1940 describes the use of an iron or cobalt insert and a copper-chrome braze for joining iron or cobalt bonded carbides (e.g., TiC) to a metal base.[166]

Two British patents describe joining cobalt-silver bonded tungsten carbide (among others) to a high thermal-expansion material using an interposed layer of a low thermal-expansion ferrous material or a layer of soft silver or copper to take up the stresses. Suitable layers of brazing solder are interposed before furnacing.[90, 91]

Apparently no further successful sandwich braze patent applications were filed from late 1938 until June 4, 1947. Then, simultaneous identical applications were filed, in the United States and in England.[22, 159] The patents describe a copper strip 0.01 in. thick, coated or laminated with a 0.005-in. layer of silver solder on either side. This sandwich is brazed at 650–800° C. The advantages claimed for this sandwich are:

1. A reduction in the amount of braze material needed.
2. Higher production efficiency.
3. No excess brazing material.
4. Improved braze strength.
5. Longer cutting wheel life since the braze is thinner.

The next five years saw an average of two braze sandwich patents and one braze sandwich article each year. In 1948, a French patent application was filed for simultaneous brazing (sinter-

* This tip is described as weld, crater and corrosion free.

ing to the base) and mechanical joining.[144] This is done by coating a strip of metal gauze (on both sides) with sintered powder and securing the uncoated ends of the gauze with clamp downs. At about the same time, (1948), a German patent application was filed for carbide inserts set with an interposed layer of copper foil and brazed with brass or a silver solder.[70]

The following year, a British patent application was filed for diamond tools fabricated by hot pressing a stack of thin disks coated with solder and diamond particles and interleaved with further disks of fine wire gauze.[131] That same year (1949) another British patent application was filed for rock drilling bits fabricated by encasing a carbide bit with metal gauze to which it might be joined by brazing or by condensed metal vapor or simply by the elasticity of the gauze. The assembly was then brazed to the steel tool at a temperature that would not affect the connection between the bit and the gauze.[59] Also, in 1949, another British patent application was filed for brazing carbide tips with pieces of steel or copper-nickel gauze coated with solder and flux by passing the strip through a bath of molten solder and molten flux.[71]

In 1950, a German patent application was filed for wedging carbide tips tightly into position with windings of iron wire and then filling the interstices with brazing material.[158] The following year a very similar patent application was filed in England. This application described positioning the tip in the tool shank recess with pieces (i.e., shims) which were wettable by the soldering or brazing filler metal used to fill the gap.[106] (See, also, reference No. 113).

In 1951, a German patent application was filed covering refinements in braze sandwich materials.[123] Four claims were made:

1. Perforated copper foil plated on both sides with silver solder.
2. Nickel gauze plated with silver solder.
3. Nickel gauze plated with copper and then encased with a foil of silver solder.
4. Mixture of silver solder powder with copper and/or nickel powder.

An interesting modification of the sandwich idea is to be found in a 1952 British patent application.[86] This application describes the joining of unlike metals, e.g., light alloys and copper, by interposing a metallic layer consisting of a metal which forms a eutectic with the light metal, melting below 600° C. The interposed layer is soldered to the copper and sintered to the light alloy. (Example: "Aluminum and/or magnesium is connected to copper, using a silver or zinc plate which is silver soldered to the copper and sintered to the light alloy through the use of a layer of powder of the same metal which comprises the plate.")

There is a lag of one to four years between filing a patent application and the granting of a patent. Therefore, insofar as the writer can determine, the foregoing represents all the patents granted prior to Aug. 15, 1956.

(*b*) *Current Acceptances of the Sandwich Braze.*

(*aa*) *Acceptance of sandwich brazes in the general literature:* Unless the discovery is commercialized at once, very little information is available about patent applications before issuance of the patent. While there is some independently sponsored research on brazing of tool tips, the bulk of the work is patentable in nature and is sponsored by industry. Therefore, most of the literature on this subject is of the state-of-the-art type, describing recent developments or current practices.

Goetzel's definitive text on powder metallurgy,[48] Vol. II, p. 223, quotes a remark by Engle.[167] Engle states that a cushioning shim may be needed between the steel and the carbide. This is one of the earlier references to braze inserts.

The first article found which mentions the established use of a "sandwich" is a 1951 German paper by Hinnuber and Hilbes ("Use of foil or gauze reduces the shear strength of the braze but is preferred since it improves alloying with both the steel and the binder metal.")[61] By 1954, the status of the sandwich braze was such that a British article described the sandwich as "a common way to overcome brazing stress,"[42] and an American article, "How to Braze Carbide Tipped Tools,"[7] advised the use of a sandwich braze for all large carbide inserts and for all Grade C-3, C-4, C-7 and C-8 carbide tips, whatever the size. The braze recommended was the patented silver-copper-silver sandwich described earlier. In 1953, Jelling described the use of a similar braze material in a fashion which "increased tool life up to 200%, by reason of the increased braze and tool cross-section area possible with a sandwich braze, and the consequent increase in tool-tip rigidity."[88] Instead of copper, the sandwich meat used was nickel. Instead of mounting the braze joint perpendicular to the plane of rotation of the work, the braze joint was mounted parallel to the plane of rotation. This placed the braze joint in shear and permitted a deep section of the carbide to serve as its own wear plate. Bonding was good if the tip was puddled ("wiped"). Use of the nickel sandwich eliminated the usual hair cracks.

(*bb*) *Acceptance of sandwich brazes by authors of standard references:* The two books on brazing, by Brooker and Beatson (1953)[23] and the American Welding Society (1955)[8] are recent enough to call attention to the increasing use of braze sandwiches. The AWS Brazing Manual states that the cracking of brazed carbides which occasionally occurs on cooling can be overcome by a sandwich braze, i.e., a shim of soft metal, e.g., copper or nickel, brazed on one side to the carbide and on the other side to the metal part. The shim is described as creeping during cooling to reduce the stress in the joint. A special braze sandwich of copper clad with nickel-bearing BAg solder is described as "available."

Brooker and Beatson discuss braze inserts in much greater detail, describing the use of iron, steel, molybdenum, copper, nickel, copper-nickel and iron-nickel inserts, as well as sandwiches with a meat of soft iron, nickel or copper-nickel. The alternative to a sandwich is described as iron gauze impregnated with solder and then the whole coated with more solder. Since this design generally provides a barely adequate gauze-to-solder ratio, the next step is a pressed and flattened compound woven gauze, the majority of the wires being braze alloy, the balance soft iron. Brooker and Beatson[23] have excellent photographs of these gauzes. They state that both gauzes and corrugated insert sheets reduce the incidence of voids by offering a large number of capillary paths for the molten braze metal. They also assert that the use of gauze inserts yields joints so thick and ductile that carbide tips can be quenched from the brazing temperature. The three primary characteristics of a good insert are:

(*a*) Joint thickness increased sufficiently (to 0.008–0.015 in.) without introducing a zone of weakness.
(*b*) Insert ductile enough to strain properly when stressed.
(*c*) Insert not dissolved excessively by the braze during the braze operation.

(2) Electrodeposits

Braze thickness can be increased by other ways than by free inserts. Prior to the increased use of a sandwich-type braze material, the most popular way of obtaining a thick joint involved electroplating. In 1941, Richards offered an extensive review of the history and the then-current procedure for electroplating joints and joining electroplated articles.[125]

A 1940 German patent application claimed the prevention of carbide tip

distortion during brazing by cathodically etching the tip with potassium hydroxide and then electrodepositing an iron coating.[3] After being coated with iron, the tip was heated to 500–1000° C in a nonoxidizing atmosphere and was then plated with "the desired metal" (e.g., the braze or another shim metal). Five years later (1945), another German patent application[43] described immersing titanium-bearing tungsten carbides in 10% copper sulfate for several hours. If the finished tool was to be subjected to high thermal and mechanical stresses, it was given a short diffusion anneal at 1000° C before being given a build-up plate of copper or nickel. The purpose of the copper sulfate soak would be to encourage galvanic displacement of the copper onto the cemented carbide. The contact between the displaced copper and receptive surfaces is sufficiently intimate to permit ready diffusion and bonding when the energy level (i.e., temperature) of the system is increased.

Goetzel concurs that one way of cushioning the carbide tip is to nickel plate the steel shank.[48] Plating, e.g., with copper or nickel, may serve the multiple purpose of prewetting[139] the carbide‡[8] and at the same time preplacing the braze metal and holding it in position.[100] If the plated-on braze metal is properly chosen, the plated part may have a much longer corrosion-free shelf life than the unplated part.[139] This often means greatly simplified production scheduling.

The matter of bonding an electroplate to the base metal without the interposition of a poorly adherent oxide film is sometimes quite difficult. For this reason, the writer would like to call attention to the nickel strike bath developed by Woods.[165] This bath, consisting of 30–40/oz gal nickel chloride and at least 16 oz/gal 38% hydrochloric acid, is extremely good for depositing an adherent nickel strike on stainless steel. The bath appears to be equally good for applying a flash or strike to many other surfaces. Cobalt and nickel-cobalt strikes have also received attention.[146]

The last three patents the writer could find on preplating of brazed refractories were filed in 1948–49, one in Germany and two in the United States. The German patent describes coating both the carbide and the shank with braze metal, either by dipping them in a molten bath or by electrolysis, prior to furnace brazing.[58] The two U. S. patents are for dental drills and make more exotic use of the electrodeposits. In one, an electroplated coating of zinc is used to prewet the ceramic by vaporizing shortly prior to melting of the braze alloy.[151] The other patent uses an electrodeposit of zinc to fix a mixture of enamel frit and diamonds to a tool shank.[141] The plated piece is then fired to smooth out the surface of the frit.

‡ *Op. cit.*, p. 155.

c. *Use of Materials with Matching Coefficients of Expansion*

A 1942 patent application[47] describes alumina cutting tips which are made with a thin sintered backing of low expansion Co-Ni-Fe. Brooker and Beatson (*op. cit.*) state that at least until 1952, the use of a sandwich with a controlled coefficient of expansion had been of very little help (see also Reference 40), but this position is complicated by the fact that the expansion coefficient of the sandwich increased sharply at temperatures well below its softening point.

Matching the coefficients of expansion can be very important. The writer was associated with the development of a tungsten-base tool shank which matches the coefficient of expansion of the carbide tip. As a result, carbide tips can be brazed on by conventional methods, using almost any braze that will wet the carbide. The resultant tool has few residual stresses and is crack free. It can therefore be used under severe extremes of load and temperature. Worn tips are easily removed by heating and replacement tips are easily brazed on. (Coykendall states that if the braze is too thick the advantage in using materials with matching coefficients of expansion is lost.[29])

(1) Preplaced Powders

Electroplates and foils serve to preplace the braze metal. Powders may also be used for this purpose. The powder technique is very good for certain special shapes.* The powder is held to the surface by an organic compound, e.g., a higher alcohol, with which it was premixed.[79] The binder distills, leaving very little residue, and the powder stays in place until it fuses.

In a rather interesting modification of the preplaced-powder technique, the oxides of at least two of the following metals, Mo, Ti, W, V, Cr, Nb, Ta and Mn, are mixed with carbon, subjected to alumino-thermal reduction, powdered, mixed with an organic cement and carbon, and then painted on the surfaces to be brazed.[100] The carbon and the metals form carbides in the brazing operation.

* Alloy powders are not always easy to prepare, particularly if the alloy is so malleable the powder cannot be ground to size. One way to overcome this difficulty is to divide the alloy ingredients into two groups. The first group will include all ductile components which can be made by hydrogen reduction. The particle size of this group may be controlled by the presence of fine, brittle, nonreducible diluents which are later removed. The second group will include any brittle alloy components which are readily crushed and ground.[130]

d. *Use of Laminated Cermets*

In addition to joint thickening, and preplacing, many other techniques are proposed for improving metal-to-cermet brazes. One procedure is to make the cermet in two or more layers,† with a titanium-rich carbide on the working side and a titanium-free carbide on the brazing side.[33] Such laminates[24, 94] may be fabricated by slip casting[60, 112] or hot pressing[56, 66, 103] or by sinter welding (four of these seven references refer to laminates which are subsequently brazed). Zones or inserts of a harder carbide[134] may be used instead of laminates.

e. *Modification of Joint Design*

As mentioned earlier, design modifications may also improve carbide braze characteristics. One modified design called for carbide inserts brazed to shanks which were in turn bolted to the main body. This was done because direct brazing would have counteracted the prior case hardening of the metal.[63] Good results were claimed for a percussion drilling bit made by brazing two pieces of steel to the bit to form a groove and then brazing the carbide insert into this groove.[133] Tensional stresses in one rock drill insert were reduced by tapering the slot so as to vary braze thickness from section to section.[6] Another rock-drill shaft was fitted with cylindrical tungsten-carbide inserts, for better braze and minimum hammering and distortion of the metal between the inserts.[59] Carbide tips coated with braze material and designed to be set by hot forging were reported to give good results.[127] In a three-month period in 1947–48, two patent applications were filed for cutting tools made by fitting carbide rings or caps over steel shafts:[109, 153] in one of these applications, the voids were filled with molten cerromatrix, a bismuth-lead-tin-antimony alloy.[109] Advantages claimed for carbide caps as compared with carbide inserts were better shock characteristics when the tips heated up.

f. *Refinement of Conventional Techniques*

(1) Surface Preparation

(*a*) *Grinding, Polishing and Cleaning.* Techniques which are important in conventional brazing are also important in cermet-to-metal brazing. Opinions may differ; for example, Goetzel states that the carbide face should be highly finished (usually in a hydrogen atmosphere)[48] while Hinnuber and Hilbes state that the surface should be prepared by sandblasting or etching with HCl.[61] (An Austrian pat-

† This was fabricated by hot pressing with multiple punches heated by external burners: punch temperatures were inversely proportional to the punch sizes. The resultant tool tip was claimed to have substantially improved transverse rupture strength and better thermal conductivity.

ent covers the use of + 100-mesh iron or copper powder for this blasting).[104] Brooker and Beatson state that very fine surfaces, such as those produced by lapping, are less conducive to copper flow than drilled, turned or shotblasted surfaces.[23] The *AWS Brazing Manual*[8] considers cleaning of carbides particularly important and believes mechanical cleaning, e.g., grinding on a diamond wheel, is more effective than chemical methods. A recent (late 1954) British article also favors light grinding as the proper method of surface preparation.[27]

(*b*) *Tinning.* A new (1956) Los Alamos developed technique combines mechanical cleaning with prewetting by loading a medium grit grinding wheel with solder.[28, 98] If a ceramic is to be tinned, it is first heated. In this case, Woods metal plus 50-50 indium-tin is used to load the grinding wheel. Then ordinary solder is used to fill the joint.[98]

Tinning is the rubbing of a surface with molten metal to wet it and is a very common practice in soldering and brazing. Wiggling (also called wiping or puddling) of carbide tips,[8, 23] referred to earlier, is a form of tinning. One special soldering iron has an iron tip: this tip is vibrated at ultrasonic frequency by a vacuum-tube-driven magnetostriction oscillator.[152] It is claimed that this not only aids in wetting clean surfaces but also removes any surface oxides still present (e.g., those normally on stainless steel, chrome plate and others).

Dawihl has suggested a method of tinning titanium- and vanadium-rich carbides[33] which involves wetting a copper plate with hydrochloric acid, then heating it to 800° C in a flux of molten borax. The carbide tip is then rubbed on this hot copper plate.

It was mentioned earlier that oxides tend to increase viscosity.[27] At least one reference therefore suggests that the solder be thoroughly deoxidized.[61] Since fluidity is not always wanted, iron powder is sometimes added to copper brazing powder just to increase its viscosity.

(2) Heat Sources

(*a*) *Induction Heating.* Heat-up rate receives much attention. Among the claims for induction heating of brazes[17, 61, 113] most are based on its speed, e.g., the writer has completed a braze in 15 sec. Standard production rates frequently exceed two brazes a minute. Short sintering times prevent diffusion and intermetallic formation and thereby minimize the disadvantages of noneutectic or multicomponent braze materials (see Fig. 9).[17, 113] A March 1956 article claims that induction brazing is now used almost exclusively in the carbide tipping of tools.[149]

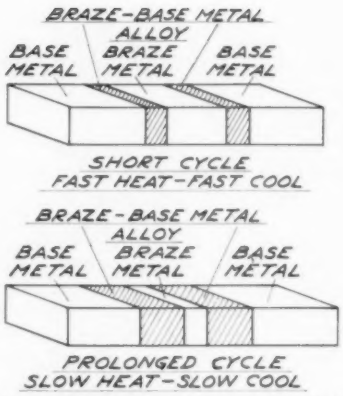

Fig. 9 Effect of heat cycle on multiple phase joints

(*b*) *Resistance Heating.* Resistance heating* may be substituted for induction heating. Since the resistance is usually greatest at the unbrazed joint, the heating effect is definitely localized. An early (1934) Russian article[130] describes the use of (*a*) ac, (*b*) dc and (*c*) dc with superimposed ac for brazing hard metals. The primary conclusion reached was that the carbide's resistance to wear was reduced in all three cases if excess current was used. A 1953 British patent application covers pulsed-current heating.[26] This is claimed to localize the heating better and to minimize stresses due to differential expansion. An American patent describes a still more novel modification of resistance brazing.[41] A semiconductor, which contains a metal oxide, possessing a negative temperature coefficient of electrical conductivity in an insulating medium, together with a small free metal content (to carry current), is placed between two electrodes in a reducing atmosphere. An arc is drawn. One of the electrodes is metal and the other carbon. The arc reduces a part of the oxide to metal which then wets and bonds to the metal electrode. The metal electrode, therefore, serves as part of the final assembly. The carbon electrode is not wetted and therefore remains separated from the rest of the assembly.

(*c*) *"Heatless" Bonding.* (*aa*) *and* (*bb*) *Solid-phase pressure welding and ultrasonic welding:* Although generally the best way, heat is not the only way to achieve a braze. Solid-phase pressure welding is receiving increased attention[154] as is ultrasonic welding.[97] While the pressure-welding technique is usually limited to certain materials with clean surfaces, the ultrasonics method is, to a degree, self cleaning and, therefore, has broader potential application.

(3) Brazing Atmospheres

Brazing atmosphere has received considerable attention. Fluxes, for example, provide their own local atmosphere. Various users favor everything from neutral to strongly reducing atmospheres. Atmospheres used include helium, argon, hydrogen, nitrogen, dissociated ammonia, cracked city gas and many others. Gas dewpoint receives definite consideration. One of the newer techniques for hard-to-braze materials is strongly concerned with the atmosphere problem.[16] The item to be brazed is placed in a high-vacuum furnace and held at a temperature of 100 to 300° C to drive off absorbed gases. A reducing gas is then introduced into the evacuated furnace and a small amount of readily oxidizable beneficiator metal is vaporized to scavenge nitrogen, oxygen and other contaminators. This evaporation may be accomplished by placing a piece of "getter" foil over a tungsten filament and then heating the filament to incandescence. The work is heated up and the protective atmosphere assures a good braze, e.g., the brazing of Co-Fe-Ni using low-pressure (40-mm) palladium-filtered hydrogen as an atmosphere and chromium as a beneficiator.

Another recommendation for carbide brazing when using copper-cobalt type brazes is to make certain that the braze metals are as carbon, silicon and phosphorus free as possible (C < 0.05%, Si + P < 0.03%).[26]

E. Special Brazing Procedures

1. BRAZING OF POROUS COMPACTS

Porous compacts present additional brazing problems. The braze goes into the pores by capillarity, leaving little braze for the joint. One procedure for overcoming this is to vacuum impregnate the compact with a low-melting alloy, e.g., Pb-Sn-Sb;[54] another is to fill the pores with colloidal graphite, which is nonwettable and nonabsorbent and therefore prevents the braze from soaking in.[88, 121] (Either oil-base or water-base emulsions have served as satisfactory graphite carriers.) A third technique involves partially impregnating a porous metallic matrix, e.g., tungsten or metallic borides, carbides or nitrides, with a ceramic. Then the outer portion is impregnated with a metal having a melting point below that of the ceramic.[92, 93]

Porosity is not always a disadvantage. In one case, a carbide or diamond die is press fitted into a porous mount of pressed and sintered metal, usually chromium steel or iron, although up to 25% zinc, lead, copper or brass powder may be added, and up to 10% lead oxide or copper oxide. Then the porous compact is impregnated with a copper alloy.[103] This two-step procedure permits inserting the carbide die before impregnation without danger of breakage, yet yields a very strong, tough

* See also References 84 and 135.

holder after impregnation.

Impregnation of a porous compact and brazing of the compact to a base may be incorporated into a single operation.* This is done by interposing a block of solder between the porous compact and the base and then heating in a reducing atmosphere.[164]

2. USE OF BRAZING PELLETS

Brazing pellets have certain application in that they provide a fixed weight and ratio of flux and braze. One such pellet combines a low-melting borate glass powder with a high-strength green brass powder.[45] The powders are pressed and sintered in order to improve resistance to crumbling; crumbling would alter the total weight and the flux-solder ratio. Quenching of such a braze is desirable because it causes the excess flux to spall off, but quenching of carbides is practicable only under the special circumstances described earlier.

3. USE OF ACTIVE METAL BRAZES

Three very useful ways to improve braze strengths are the use of the molybdenum-manganese process or titanium, zirconium or columbium-titanium, or their hydrides, to wet the cermet. Greenwood reviewed the latter two techniques in 1952 in one of his many British articles[52, 55] on powder metallurgy.

F. Use of the Mo-Mn, the Active Metals and the Active Metal Hydrides Processes in Metal-to-Cermet Bonding

Williams describes the Mo-Fe mechanism as one "which forms molybdenum—iron silicates on the ceramic."[163] Formation of silicates will probably not occur in metal-to-cermet bonding; however, since the oxides of a Mo-Mn metal will bond to other oxidized surfaces, the Mo - Mn process can probably be used. While molten titanium metal will not instantaneously wet titanium carbide (with its usual overlying oxide film), the active metal hydrides with their greater chemical activity upon decomposition may prove more effective.†

Pearson, in reviewing the Mo - Mn, the hydride and the active metals techniques, shows that all have at least one thing in common:[117] all are based on metals which, because of atomic size and chemical properties, exhibit an affinity for chemical bonding with ceramics. These metals are all relatively easily oxidized, yielding refractory oxides which are compatible with the oxides in the ceramics. These metals are: titanium and zirconium of atomic Group IVA; chromium and molybdenum, of Group VIA; manganese, of Group VIIA; iron, cobalt and nickel, of Group VIII. They bear the atomic numbers 22, 24, 25, 26, 27, 28, 40 and 42. A check of the periodic table indicates that almost all elements of primary interest in brazing and bonding fall between groups IVA and IV. Additional references on the subject of the common bonding mechanism are Jerkins,[69] Pincus[119] and Kingery.[77]

Pincus[119] quotes Pulfrich's eight rules; the more pertinent of these are:

1. Select a metal with a melting point about 200° C higher than the metallizing temperature used.
2. Select a ceramic that has a eutectic bond which melts at 300° C or more below the ceramic bulk deformation temperature, and about 200° C below the metallizing temperature. (The eutectic should not seep out of the ceramic during metallizing.)
3. Select a ductile solder with a melting point below that of the lowest temperature eutectic in the ceramic.
4. Select a metal whose expansion coefficient matches that of the ceramic as closely as possible.

(The other four rules may be found in many references to the work of Pincus and of Pulfrich.)

G. Physical Testing of Brazes

Any quality control procedure requires determination of the physical properties of the item under consideration. Braze shear strength and ultimate tensile strength tests are destructive in nature, as is the fracture test.[11] Among the nondestructive braze tests used are a British adhesion test[18] (a galvanometer test) and an ultrasonic generator test. The ultrasonic braze test is useful only for indicating reproducibility, and if properties of the base metal are inconsistent, it is almost impossible to attach any significance to the wave patterns. In ideal cases, the ultrasonic test or the measurement of differences in electrical or thermal conductivity might provide useful information about the braze, but it is the writer's experience that most cases are *not* ideal cases.

One article describes a special soldering machine which permits reproducible time-temperature-mass testing of brazes.[57] While destructive testing of these brazes gives an indication of relative braze perormance, it is only a guide and not a true control check. In view of these problems, it is quite important to pretest the braze materials. In one simple test, a pair of twisted wires (at room temperature) is inserted into a braze bath.[136] The capillary rise between the wires indicates the wetting ability of the braze. In another test, maximum bubble pressure apparatus is used to measure viscosity and surface tension.[51] The writer believes that the best way to assure a good braze (if operating costs permit) is to choose materials and techniques that offer good reproducibility of results over a wide range of operating conditions. Routine testing then becomes more a matter of academic interest than a necessity.

IV. CONCLUSION

The use of hydride, active metals and Mo - Mn surface preparation techniques, together with the use of high-temperature braze metals and base metals with matching thermal coefficients of expansion, appears quite promising. The general problem of joining metals to cermets may soon have a practical solution.

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* Another two-in-one operation is the joining of carbides to a carrier by placing the two together and then spraying them, e.g., with 10–30% copper, balance iron. The spray both coats and bonds the carbide.[35]

† Burnside states that molten copper and silver will form nonwetting spheres on glass or ceramic. If held molten on the ceramic surface, these metal droplets will hold their shape but will adhere to the ceramic because of a chemical reaction.[35] Time and reaction rates are therefore important factors.

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PLASTIC DESIGN OF THICK-WALLED PRESSURE VESSELS

Main methods for determining strength of thick-walled cylinders subjected to internal pressure are reviewed, and a new theory providing a simple approximate design formula is proposed

BY JOSEPH MARIN AND F. P. J. RIMROTT

SUMMARY. This paper gives a critical review of theories used for the design of thick-walled cylindrical pressure vessels. An evaluation of experimental results shows that much of the data is incomplete and cannot be used to determine the accuracy of the theories. In some cases, the comparison of the test data with the available theories shows poor agreement between theoretical and actual values. In other cases, the theories are unsatisfactory because they are either empirical in nature, they have an unsound theoretical basis, or the assumptions upon which they are based are incorrect. For these reasons, a new theory was developed. This theory is one which considers the plastic range of the material. It determines the maximum or instability internal pressure that can be applied to a thick-walled cylindrical vessel closed at the ends. Based upon this pressure, a design relation is obtained for the determination of the wall thickness.

The theory proposed* differs from most other plasticity theories, since it is based upon the true stress-strain tension relation of the material. It differs from all the other theories in considering that finite or large strains are produced. Furthermore, the new theory assumes an analytical tension stress-strain relation, thereby eliminating the time-consuming procedure of numerical or graphical integration required by some of the other theories proposed. A comparison of the maximum pressure, as defined by the proposed theory, with test results shows that it is in approximate agreement with these test data. It can also be noted that the proposed theory is in as good agreement with test data as any of the other theories, and it has the merit that it is based upon sounder assumptions than are used in other theories.

In order to provide a theory which can be easily applied by the designer, an approximate design formula is developed in this paper based upon the proposed theory.

Introduction

The wall thickness of pressure vessels is usually determined based upon theories and methods which consider the yield or ultimate strength in simple tension. These theories and methods have been thoroughly reviewed by Burrows, *et al.*[2] In using the simple tensile yield or ultimate strength as a basis of failure, the plastic deformation properties of the material are not considered. That is, the usual theories would assume that two materials with the same tensile yield and ultimate strengths but different ductilities are equally satisfactory. It is well known, however, that this is not the case, since ducility affords an added insurance factor by providing an opportunity for redistribution of stresses throughout the wall of the cylinder.

When design relations are used based upon the yield strength, the factor of safety selected does not give an accurate measure of the safety, since the failure criteria of the vessel should consider both the maximum and fracture pressures. In other words, the designer needs to know the factors of safety based upon the maximum and yield pressures in order to give a complete basis for design. With these considerations in mind, theories of failure for cylinders are reviewed in this study based upon both the yield and ultimate strength and considering the plastic range of the material.

Table 1—Empirical Methods for the Prediction of Maximum Pressure

Equation no.	*Name and reference*	*Formula*
1	Faupel and Furbeck[3]	$\frac{p_m}{\sigma_u'} = \frac{2}{\sqrt{3}} \frac{\sigma_{yp}'}{\sigma_u'} \left(2 - \frac{\sigma_{yp}'}{\sigma_u'}\right) \log_e \frac{b}{a}$
2	Cook and Robertson[5]	$\frac{p_m}{\sigma_u'} = \frac{(b/a)^2 - 1}{(b/a)^2 + 1}$
3	Blair[6]	$\frac{p_m}{\sigma_u'} = \frac{(b/a)^2 - 1}{\sqrt{(b/a)^2 + 1/2[(b/a)^3 + 3]} + (b/a)^4}$

Review of Available Strength Theories for Thick-Walled Cylindrical Pressure Vessels

Methods which have been used for predicting strength of thick-walled cylindrical vessels include empirical procedures and methods using theories of failure based upon the yield strength, ultimate strength or fracture strength of the materials. In addition, several theories have been proposed which consider the tensile plastic stress-strain relation of the material. A brief discussion of these methods for predicting strengths of thick-walled pressure vessels will now be given.

Empirical Methods

An empirical equation (1) has been proposed by Faupel and Furbeck[3] for predicting the maximum pressure that a thick-walled cylinder can withstand. Table 1 gives this empirical equation defining the maximum pressure. The definition of the symbols used in Tables 1 to 6 are:

r_1 = actual radius of cylinder.
a and b = original inner and outer radii of cylinder.
a_1 and b_1 = actual inner and outer radii of cylinder.
σ_{yp}' = tensile yield strength.

Joseph Marin and **F. P. J. Rimrott** are associated with the Department of Engineering Mechanics at the Pennsylvania State University, University Park, Pa.

* After the completion of this study, a similar theory[1] to that herein proposed was published.

σ_u' = nominal ultimate tensile strength.
p = yield pressure.
p_m = maximum pressure.
k and n = material constants in tension relation.
α = slope of stress-strain diagram assuming linear strain hardening.
ϵ_{yp} = tensile strain at yield.
r = shear stress.
ν = Poisson's ratio.
$\bar{\sigma}$ = significant true stress.
$\bar{\epsilon}_b$ and $\bar{\epsilon}_a$ = significant true strain at inner and outer edge of cylinder.
ϵ_{ta} and ϵ_{tb} = tangential true strains at inner and outer edge of cylinder.

Tests by Faupel[4] indicate good agreement between these tests and the proposed relation. It should be noted that an equation which has an empirical basis cannot be expected to apply to conditions not covered by the tests upon which the relation is based. In other words, a fundamental relation cannot be obtained unless a theoretical basis is used for the relation.

An equation which may be classified as an empirical relation was proposed by Cook and Robertson[5] based upon the assumption that the maximum stress value (as determined from theory of elasticity and based upon Hooke's Law, called Lamé's Formula) can be applied to predict the maximum pressure in the plastic range. It is also assumed in obtaining this equation that the Rankine's maximum-stress theory of failure applies. Based upon these assumptions, eq 2 in Table 1 is obtained for the maximum pressure. Their recommendation is based upon the fairly close agreement obtained between the maximum pressure defined by eq 2 and the experimental values they obtained.

Another empirical formula, eq 3 in Table 1, was proposed by Blair.[6] This formula assumes that the elastic stress values, as determined by Lamé, applies to the plastic range. Furthermore, the strain-energy theory for elastic failure is assumed to be applicable for defining failure in the plastic range. A value of Poisson's ratio equal to 0.25 is used, since this value was found to give best agreement with the test results by Cook and Robertson.

Methods Based Upon Beginning of Yielding

The most commonly proposed methods of design based upon the yield strength have been summarized by Buxton and Burrows.[7] Table 2 lists these various formulas based upon yield strength.

The so-called "common" formula (eq 4 in Table 2) uses Rankine's maximum stress theory of failure and assumes that the stress is uniformly distributed.[7] Assuming that the pressure acts on the average diameter or the outside diameter in place of the inside diameter, the "average" formula and the well-known Barlow formula are obtained (eqs 5 and 6—Table 2).

Another group of formulas have been proposed based upon the more accurate Lamé's theory for determining stresses. These formulas assume the stress, shear, strain, strain energy and distortion energy theories for elastic failure (see eqs 7 to 11 in Table 2).

Equation 7 assumes the maximum stress or Rankine theory, and is used as the basis for design of pressure vessels, as specified in the ASME Code for Unfired Pressure Vessels, for vessels with a wall ratio b/a of more than 1.5. For wall ratios equal to or less than 1.5, the Code specifies an approximate formula suggested by Boardman[8] and expressed by eq 12 in Table 2.

Methods Based Upon Total Yielding

Turner [10] and Nadai[11] have proposed formulas for predicting total yielding throughout the wall of a thick-walled pressure vessel. They both assumed a material without strain hardening. Based upon the shear theory Turner obtained eq 13 in Table 3, while based upon the distortion energy theory Nadai obtained eq 16. Beliaev and Sinitskii[22] considered materials with strain hardening and assumed the true stress-strain relation in simple tension to be expressed by $\sigma = k\epsilon^n$. Based upon the maximum shear and the octahedral shear as a basis for failure, they obtained eqs 15 and 16 in Table 3.

Methods Based Upon Ultimate Strength

Formulas have been proposed based upon the ultimate strength, an assumed average stress throughout the wall and a theory of failure. Following an approach by Soderberg,[9] one such formula is based upon the assumption that failure is a function of the significant stress or the octahedral shear stress. By this hypothesis, the maximum pres-

Table 2—Methods for the Prediction of Pressure Based Upon Beginning of Yielding

Equation no.	Name and reference	Formula
4	Common[2]	$\frac{p}{\sigma_{yp}'} = \frac{b}{a} - 1$
5	Average stress[2]	$\frac{p}{\sigma_{yp}'} = 2\frac{(b/a) - 1}{(b/a) + 1}$
6	Barlow[2]	$\frac{p}{\sigma_{yp}'} = \frac{(b/a) - 1}{b/a}$
7	Lamé[2]	$\frac{p}{\sigma_{yp}'} = \frac{(b/a)^2 - 1}{(^1/a)^2 + 1}$
8	Guest (Tresca)[2]	$\frac{p}{\sigma_{yp}'} = \frac{1}{2}\frac{(b/a)^2 - 1}{(b/a)^2}$
9	Clavarino[2]	$\frac{p}{\sigma_{yp}'} = \frac{(b/a)^2 - 1}{(1 + \nu)(b/a)^2 + (1 - 2\nu)}$
10	Beltrami[2]	$\frac{p}{\sigma_{yp}'} = \frac{(b/a)^2 - 1}{\sqrt{2(1 + \nu)(b/a)^4 + 3(1 - 2\nu)}}$
11	Von Mises[2]	$\frac{p}{\sigma_{yp}'} = \frac{1}{\sqrt{3}}\frac{(b/a)^2 - 1}{(b/a)^2}$
12	Boardman[8]	$\frac{p}{\sigma_{yp}'} = \frac{(b/a) - 1}{0.6(b/a) + 0.4}$

Table 3—Methods for the Prediction of Pressure Based Upon Total Yield

Equation no.	Name and reference	Formula
13	Turner[10]	$p/\sigma_{yp}' = \log_e (b/a)$
14	Nadai[11]	$p/\sigma_{yp}' = \frac{2}{\sqrt{3}} \log_e (b/a)$
15	Beliaev-Sinitskii[22]	$p/\sigma_{yp}' = \frac{1}{2n}[(b/a)^{2n} - 1]$
16	Beliaev-Sinitskii[22]	$p/\sigma_{yp}' = \frac{1}{\sqrt{3}n}[(b/a)^{2n} - 1]$

Table 4—Methods for the Prediction of Maximum Pressure Based Upon Ultimate Tensile Strength

Equation no.	Name and reference	Formula
17	Soderberg[9]	$\frac{p_m}{\sigma_u'} = \frac{4}{\sqrt{3}}\left(\frac{(b/a) - 1}{(b/a) + 1}\right)$
18	Maximum stress	$\frac{p_m}{\sigma_u'} = \frac{b}{a} - 1$
19	Maximum shear stress	$\frac{p_m}{\sigma_u'} = 2\left(\frac{(b/a) - 1}{(b/a) + 1}\right)$

sure is defined by eq 17 in Table 4.

Other ultimate strength relations based upon an average stress and various theories of failure, such as the maximum stress and shear theories, can be expressed as given by eqs 18 and 19 in Table 4. These relations, as well as the one proposed by Soderberg in eq 17, can only be considered as approximate since the assumption of uniform stress distribution may introduce considerable error. In order to provide correctly for the stress distribution, the plastic range must be considered. In the following methods, the plasticity of the material is taken into account.

Methods Based Upon the Plasticity of the Material

Various approximate methods of considering the plastic range in a cylinder have been proposed. These methods define the ultimate strength of thick-walled cylinders based upon simplified assumed stress-strain relations. Turner[10] developed a formula assuming the material to be perfectly plastic with no strain hardening. Assuming infinitesimal or small strains and the maximum-shear theory of failure, eq 20 in Table 5 was obtained for the maximum pressure in terms of the nominal tensile ultimate strength of the material.

If a perfectly plastic material is assumed but the octahedral shear stress in place of the maximum shear stress is used as the failure relation, Nadai[11] obtained eq 21 in Table 5 for the maximum pressure in terms of the nominal tensile ultimate strength of the material.

Assuming strain hardening and that the nominal stress-strain relation can be expressed by a straight line, Burrows[2] obtained an expression for the maximum pressure based upon both the octahedral and the maximum shear stress criteria for the plastic range. The maximum-pressure relations proposed by Burrows are represented in eqs 22 in Table 5.

Using the torsion stress-strain n-power relation in place of the tension stress-strain relation $\sigma = k\epsilon^n$, as suggested by Nadai,[11] Bailey[13] determined a theoretical equation for the maximum pressure based upon the maximum shear stress plasticity relation. Equation 23 in Table 5 defines this maximum pressure in terms of the nominal ultimate strength. This equation has been referred to as the Bailey-Nadai equation.

Based upon the tension stress-strain relation expressed by the n-power relation and assuming the significant stress-strain plasticity relation, Nadai[12] obtained the maximum pressure relation represented by eq 24 in Table 5.

The foregoing methods of defining the maximum pressure are based upon considering the plastic range and using some theory of failure for defining the ultimate strength. Another method of approach is to determine an expression for the pressure considering the plastic range and using a theory of plasticity for expressing the stress-strain relation. Using this basis for expressing the pressure in the plastic range, the maximum or instability pressure is then obtained from the condition that maximum pressure occurs when $dp = 0$. Theories of this type have been developed by Manning,[14] Jorgensen,[15] MacGregor, Coffin and Fisher,[16] Beeuwkes and Laning,[17] Nadai[12] and Hu.[18]

Manning[14] applied a theory of plasticity for finding the instability pressure, by using the maximum-shear theory together with the shear stress-strain diagram obtained by a torsion test as suggested by Nadai.[11] A numerical integration method is then used to find the maximum pressure. The value of this pressure can be expressed by eq 25 in Table 6. MacGregor, *et al.*[16] obtained the maximum pressure as given by eq 26 in Table 6, by using the significant stress-strain plasticity relation in place of the maximum shear theory and defining the theory in terms of simple tension rather than pure torsion. Nadai[12] used the octahedral shearing stress plasticity relation instead of the maximum shear theory and obtained the maximum or instability pressure as expressed by eq 27 in Table 6. Both eqs 26 and 27 require a numerical or graphical integration procedure since neither MacGregor nor Nadai attempt to express the tensile stress-strain relation by an equation. Jorgensen[15] uses an approach similar to Manning's[14] but proceeds from a stress-strain relation obtained from a simple tension test. He evaluated an approximate maximum pressure as given by eq 28 in Table 6. Beeuwkes and Laning[17] used the same approach as MacGregor, *et al.*[16] but assumed a linear true stress-strain relation for simple tension in the plastic range instead of the actual stress-strain relation. The maximum or instability pressure is then defined by eq 29 in Table 6.

A theory for the determination of the maximum pressure based upon the use of Langrangian strains was proposed by Hu.[18] Using the n-power law for

Table 5—Methods for the Prediction of Maximum Pressure Based Upon the Theory of Plasticity

Equation no.	*Name and reference*	*Formula*
20	Turner[10]	$\frac{p_m}{\sigma_u'} = \log_e \frac{b}{a}$
21	Nadai[11]	$\frac{p_m}{\sigma_u'} = \frac{2}{\sqrt{3}} \log_e \frac{b}{a}$
22	Burrows[2]	$\frac{p_m}{\sigma_u'} = A \frac{\log_e \frac{b}{a} + \frac{1}{2}\left[\left(\frac{b}{a}\right)^2 - 1 - 2\log_e \frac{b}{a}\right] \frac{\epsilon_{yp}'}{\sigma_{yp}'} \tan \alpha}{1 + \left[\left(\frac{b}{a}\right)^2 - 1\right] \frac{\epsilon_{yp}'}{\sigma_{yp}'} \tan \alpha}$ $A = \frac{2}{\sqrt{3}}$ for v. Mises $A = 1$ for Tresca
23	Bailey-Nadai[13]	$\frac{p_m}{\sigma_u'} = \frac{1}{2n}\left[1 - \left(\frac{a}{b}\right)^{2n}\right]$
24	Nadai[12]	$\frac{p_m}{\sigma_u'} = \frac{1}{\sqrt{3}n}\left[1 - \left(\frac{a}{b}\right)^{2n}\right]$

Table 6—Methods for the Prediction of Pressure Based Upon Theory of Plasticity and Finite Strains

Equation no.	*Name and reference*	*Formula*
25	Manning[14]	$p = 2\int_{a_1}^{b_1} \frac{\tau}{r_1} dr_1$
26	MacGregor[16]	$p = \frac{2}{\sqrt{3}} \int_{a_1}^{b_1} \frac{\sigma}{r_1} dr_1$
27	Nadai[12]	$p = 3\sqrt{\frac{2}{3}} \int_{a_1}^{b_1} \frac{\tau_{oct}}{r_1} dr_1$
28	Jorgensen[15]	$\frac{p_m}{\sigma_u'} = \frac{1}{\sqrt{3}}\left(1 + \frac{\sigma_b'}{\sigma_u'}\right) \log_e \frac{b_1}{a_1}$ where σ_b' is taken from a work chart in Jorgensen's paper
29	Beeuwkes and Laning[17]	$p = \frac{2}{\sqrt{3}} \sigma_{yp}' \log_e \frac{b_1}{a_1} + \frac{\tan \alpha}{3} \sum_{\nu=1}^{\infty} \frac{(1 - e^{-\sqrt{3}\epsilon_{ta}})^\nu - (1 - e^{-\sqrt{3}\epsilon_{tb}})^\nu}{\nu^2}$
30	Hu[18]	$p = \frac{1}{2k^{1/n}} \left(\frac{4}{3}\right)^{\frac{n+1}{2n}} \left\{\frac{1}{n} \epsilon_{ta}{}^n \times \left(1 - \frac{3n}{1+n}\epsilon_{ta} + \frac{5n}{2+n}\epsilon_{ta}{}^2 - \frac{10n}{3+n}\epsilon_{ta}{}^4\right) - C_2\right\}$ where $C_2 = -\frac{1}{2}\log_e \epsilon_{tb} + \frac{\epsilon_{tb}}{2} - \frac{\epsilon_{tb}{}^2}{4} + \frac{\epsilon_{tb}{}^3}{3} - \frac{3\epsilon_{tb}{}^4}{8}$ for $\epsilon_t < 0.5$

the stress-strain relation in simple tension, a closed form solution is obtained for the pressure as a function of the expansion of the cylinder. Equation 30 in Table 6 expresses the value of the maximum pressure by this method of analysis.

A comparison of the maximum pressures as given for each group of methods discussed in the foregoing, is shown in Figs. 1, 2, 3, 4 and 5. An examination of these figures shows that there is considerable difference in the predicted maximum pressure as defined by the various available methods.

Later in this paper, a comparison is given between the maximum-pressure values as predicted by the various theories and as determined by tests. This comparison indicates that the theoretical prediction of the maximum pressure might be improved. With this in mind, the following theory was proposed.

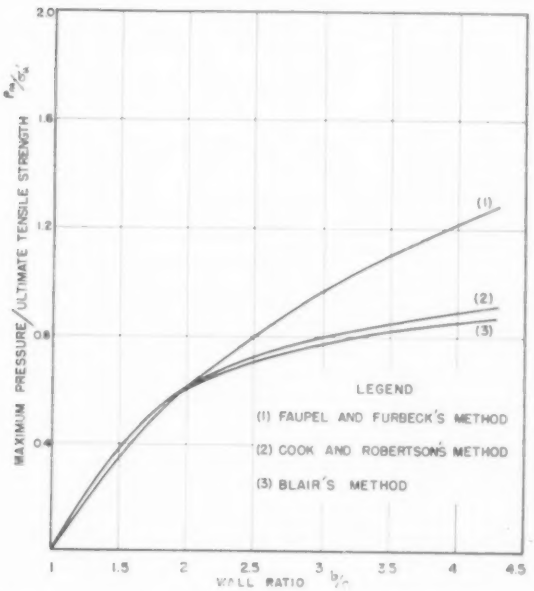

Fig. 1 Empirical methods for prediction of maximum pressure

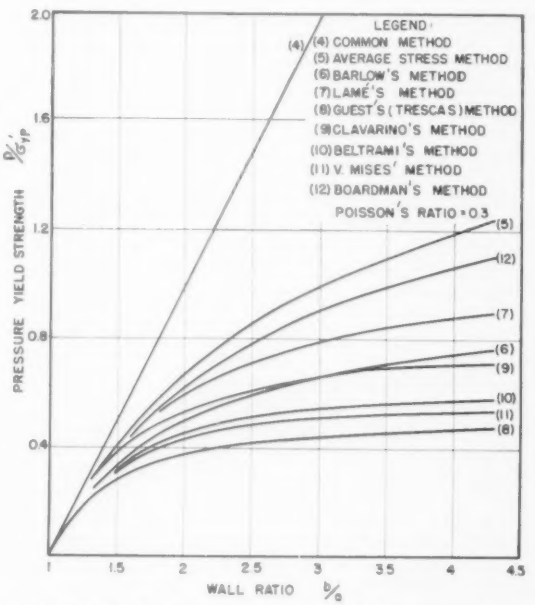

Fig. 2 Methods for prediction of yield pressure based upon the yield strength

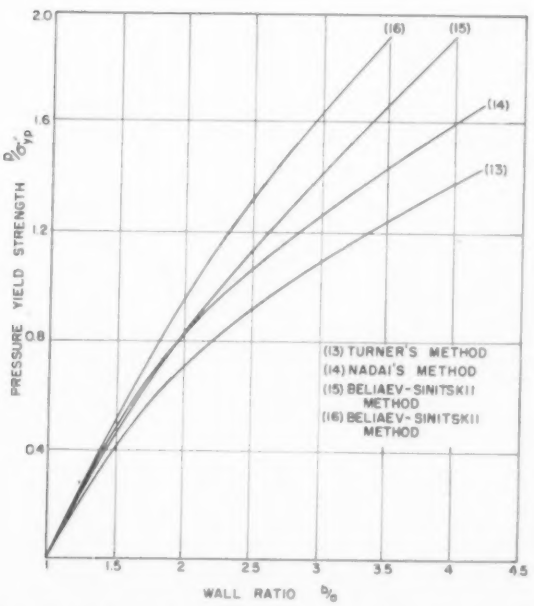

Fig. 3 Methods for prediction of total yield pressure based upon the yield strength

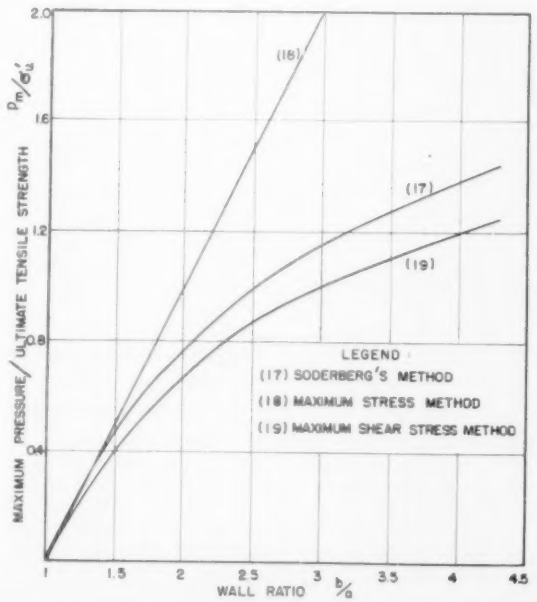

Fig. 4 Methods for prediction of maximum pressure based upon the ultimate strength

Proposed Theory for Strength of a Thick-Walled Cylinder Based Upon Instability

Most of the methods for predicting the maximum pressure in a thick-walled cylinder can be discarded on the basis that the methods are either empirical; they are based upon incorrect assumptions; or they use as a basis the shear stress-strain relation as obtained from the torsion of a solid round specimen. Furthermore, some methods that have been proposed are inconvenient to apply, since the maximum pressure is expressed in terms of an integral which must be solved by graphical or numerical integration. The method proposed* is similar to Nadai's method[11] except that the tensile true stress-strain relation is used in place of the shear stress-strain relation. It also expresses this relation in closed form and in this respect, it differs from the method proposed by Jorgensen.[15] It is also expected that the use of large or finite strains in the proposed theories (in place of small or infinitesimal strains) will lead to a more accurate prediction of the maximum pressure than is possible with other theories.

The proposed theory for the maximum pressure cannot be used directly for design purposes. For this reason an approximation to the exact maximum pressure relation was evaluated. By this approximation the maximum pressure is defined by

$$p_m = \left[\frac{2\sigma_u'}{\sqrt{3}(1+\epsilon_u')}\right]\left(\log_e \frac{b}{a}\right) \quad (31)$$

where:

σ_u' = the nominal or conventional ultimate tensile strength of the material.

ϵ_u' = the nominal or conventional strain corresponding to the nominal ultimate stress.

a and b = the inner and outer radii of the cylinder.

e = base for material logarithms.

Figure 6 shows a comparison between the "exact" and approximate maximum pressure eq 31. An examination of examination of Fig. 6 shows that eq 31 gives a good approximation for the maximum pressure. Equation 31 is valid for wall ratios of at least up to b/a = 5. This means that the formula can be used in practically all cases since actual vessels rarely have wall ratios greater than b/a = 5.

Comparison of Theoretical and Experimental Values of Maximum Instability Pressures

Some of the methods used for predicting the maximum pressure in a thick-walled cylinder can be discarded because of the empirical basis of the method or because of the assumptions made in the theory. For this reason, comparison between predicted and experimental maximum pressures will only be made based upon the Nadai eq 24, the proposed "exact" method, and the proposed approximate method. The empirical eq 11 suggested by Faupel[3] will also be included to show that the proposed theory gives a prediction of maximum pressures which is as good as the "curve fitting" empirical procedure proposed by Faupel. It is unnecessary to note that under these circumstances, a method based upon theory is preferable to an empirical procedure.

An examination of the test data shows that few experimental investigations on strength of thick-walled cylinders have been reported. These include the experimental studies made by Deffet and Gelbgras,[19] Crossland and Bones,[20] Cook and Robertson,[5] Faupel and Furbeck[3] and Faupel.[4]

A comparison of the test results obtained by Deffet and Gelbgras,[19] Crossland and Bones,[20] Cook and Robertson,[5] Faupel and Furbeck[3] and Faupel,[4] with the selected methods of predicting the maximum pressure as indicated above, shows that, in general, there is approximate agreement between the actual and predicted maximum pressures. On the basis of the percentage differences, there does not appear to be any best method. However, the proposed "exact" or approximate methods are recommended over Nadai's method since these methods are based upon the more accurate assumption of large or finite strains rather than small strains. As previously noted, the empirical method proposed by Faupel[1] is not recommended because it is based upon an empirical equation and not upon a theory. Since the proposed approximate method agrees with the test results as well as the proposed "exact" method, it will be recommended for design purposes because it is simpler to use.

Errors in Interpretation of Test Results

In many cases, the test results obtained cannot be considered adequate since in most investigations, check tests were not made. Test results using

* The proposed theory is developed in a bulletin entitled "Design of Thick-Walled Cylinders Based on the Plastic Range" to be published by the Welding Research Council.

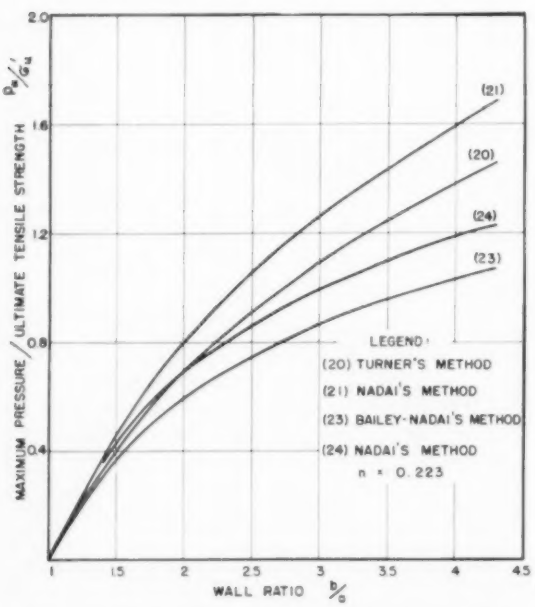

Fig. 5 Methods for prediction of maximum pressure based upon theory of plasticity

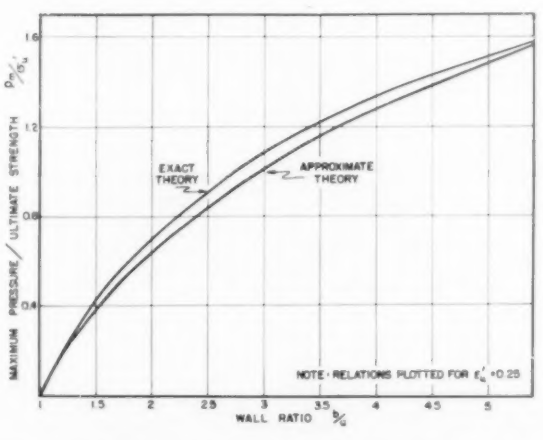
MAXIMUM PRESSURE / ULTIMATE STRENGTH p_m/σ_u'
WALL RATIO b/a
EXACT THEORY
APPROXIMATE THEORY
NOTE - RELATIONS PLOTTED FOR ϵ_u' = 0.25

Fig. 6 Comparison between exact and approximate formula

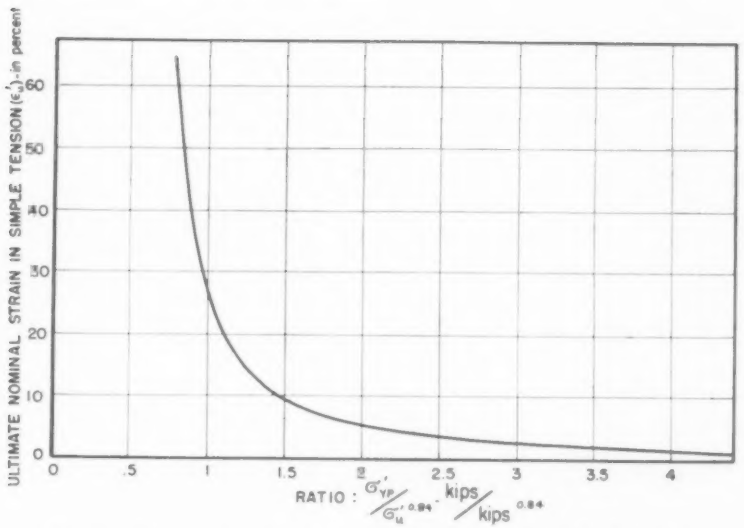

Fig. 7 Diagram for the determination of ultimate strain for steel

six cylinders of the same size and material were obtained by Deffet and Gelbgras.[19] These results show a scatter of 7% or more in the maximum pressure. Results obtained from only one test can therefore only be considered as approximate.

Another difficulty encountered in the interpretation of the data was the lack of complete information on the plastic true stress-strain results in simple tension. In order to develop methods for predicting maximum pressure based upon a theory of plasticity, the tensile stress-strain data is required. In the interpretations made in this paper, the log-log tension relation $\sigma = k\epsilon^n$ was used. To obtain k and n in the tension relation, the theoretical result that $\epsilon_u = n$ was assumed. Then from the equation $\sigma = k\epsilon^n$

$$k = \frac{\sigma_u}{\epsilon_u{}^n} = \frac{\sigma_u}{\epsilon_u{}^{\epsilon_u}} \qquad (32)$$

Equation 32 can now be used to find k, provided both σ_u and ϵ_u are known. With the exception of some data reported by Faupel,[4] information for obtaining the strengths σ_u and the strains ϵ_u are not given. In order to interpret the available test data on thick-walled cylinders, it was therefore found necessary to determine ϵ_u from the nominal strain ϵ_u' as defined in an empirical relation proposed by Janitzky and Baeyertz.[21]* Figure 7 gives the values of these strains ϵ' as a function of σ_{yp}'/σ_u'. The use of an empirical equation for finding the strain ϵ_u' may of course introduce some error in the evaluation of both k and n. In turn, these possible errors may influence the value of the maximum pressure predicted by the theory herein proposed.

Other sources of errors in the interpretation of the data include the possible influence of differences between the speed of loading of the tensile specimen and the pressure in the cylinder, lack of homogeneity and isotropy of the material tested, and influence of experimental errors (as for example, errors in the measurement of pressure).

Another possible error in the interpretation is that the maximum pressure may be first reached by failure in some other manner than instability. That is, failure may occur by a cleavage fracture or by a shear sliding type of failure.

The reliability of the test results is difficult to determine. Of the test results reported, only those of Deffet and Gelbras appear to be reliable since they are the only ones that include check tests. However, test results by Crossland and Bones may also be considered as satisfactory since an average result is obtained by testing cylinders of the same material but with different wall ratios. A plot of the test results obtained by Crossland and Bones (as shown in Fig. 8) confirms the foregoing observation.

Proposed Design Procedure for Thick-Walled Cylinders

In Section VIII of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels, the allowable pressure is defined by the following equations:

For $b/a \leq 1.5$,

$$p_w = \left[\frac{\frac{b}{a} - 1}{0.6\,\frac{b}{a} + 0.4}\right]\sigma_w \qquad (33)$$

For $b/a > 1.5$,

$$p_w = \left[\frac{\left(\frac{b}{a}\right)^2 - 1}{\left(\frac{b}{a}\right)^2 + 1}\right]\sigma_w \qquad (34)$$

where:

σ_w = the working stress.

Equation 34 is based upon the Lamè equation for elastic stress and eq 33 is Boardman's approximation of eq 34. Since eq 34 is based upon the elastic range, it does not consider the influence of plasticity and ductility upon the strength of the cylinder. The proposed theory on the other hand does provide for ductility and is based on the consideration of the plastic range of the material. The allowable pressure by the proposed approximate eq 31 can be obtained by dividing the maximum pressure by a factor of safety N. That is,

$$p_w = \left[\frac{2\log_e b/a}{\sqrt{3}(1+\epsilon_u')}\right]\left(\frac{\sigma_u'}{N}\right) \qquad (35)$$

In order to compare the allowable pressure defined by the Boiler Code, with the proposed value as given by eq 35, a comparison will be made for equal allowable tensile stresses σ_w. Then replacing σ_u'/N in eq 35 by σ_w,

$$p_w = \frac{(2\log_e b/a)\sigma_w}{\sqrt{3}\,(1+\epsilon_u')} \qquad (36)$$

A comparison between the allowable pressure as defined by the ASME Boiler Code and the proposed relation is shown in Fig. 9 for various values of ϵ_u', corresponding to typical pressure vessel materials. From Fig. 9, percent differences in wall thickness between the Code and the proposed relations can be found for possible values of b/a. These differences, as given in Table 7, indicate that there can be considerable difference between wall thickness values as required by the ASME Code and as defined by the proposed formula.

Conclusions

This paper gives a critical review of the main methods for determining the strength of thick-walled cylinders subjected to internal pressure. A comparison between experimental and theoretical values of the maximum pressures is then made. A new theory providing a simple approximate design formula is proposed. This proposed theory is based upon a consideration of the plastic range and agrees with test data as well as any other proposed methods. It is similar to a theory proposed by Nadai but is based upon the more accurate assumption of large or finite strains.

It should be noted that the proposed design formula considers more accurately material properties, since the allowable pressure is not only a function of the strength but also of the ductility of the material (as defined by the ultimate strain).

* The equation proposed for determination of the nominal strain ϵ_u' is $(1 + 0.01\,\epsilon_u')^{0.84}/(\epsilon_u')^{0.84} = 0.231\,\sigma_{yp}'/(\sigma_u')^{0.84}$ where ϵ_u' is given in percent, and σ_{yp}' and σ_u' in 1000 psi obtained from a 0.505-in. diam specimen with a 2-in. gage length.

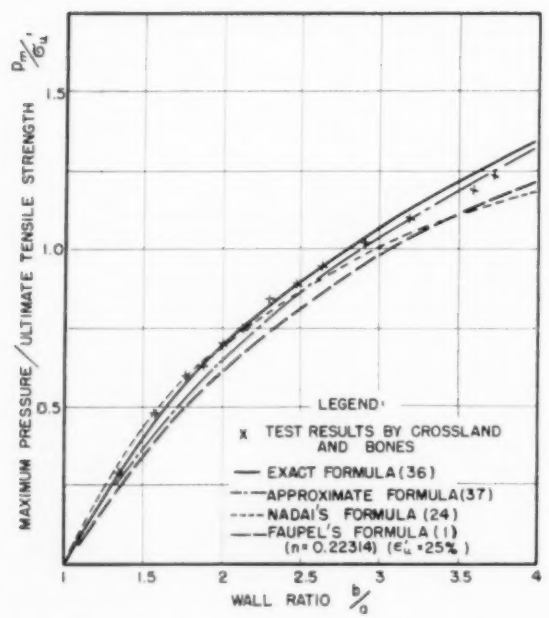
MAXIMUM PRESSURE / ULTIMATE TENSILE STRENGTH
WALL RATIO b/a
LEGEND
TEST RESULTS BY CROSSLAND AND BONES
EXACT FORMULA (36)
APPROXIMATE FORMULA (37)
NADAI'S FORMULA (24)
FAUPEL'S FORMULA (1) (n = 0.22314) (ε'u = 25%)

Fig. 8 Variation of maximum pressure with wall ratio and experimental results

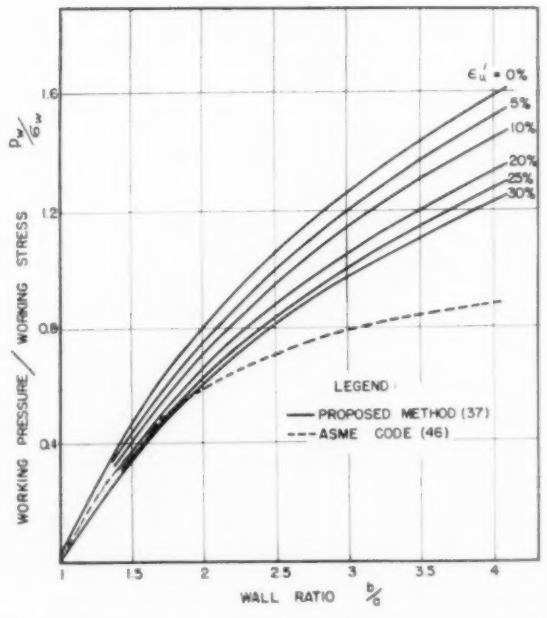

Fig. 9 Comparison between ASME Code and approximate formula

Table 7—Comparison Between ASME Code and Proposed Approximate Formula

		Percent Difference R					
p/σ_w	b/a	$\epsilon_u' = 0\%$	$\epsilon_u' = 5\%$	$\epsilon_u' = 10\%$	$\epsilon_u' = 20\%$	$\epsilon_u' = 25\%$	$\epsilon_u' = 30\%$
0.25	1.29	20	13	9	−1.6	−2	−10
0.50	1.73	36	26	10	6	0.7	−5
0.8	3.00	100	85	69	56	7	39

Note:

Values of $R = \dfrac{t_a - t}{t}$ for a given bore radius a = constant

where t = wall thickness by proposed formula, t_a = wall thickness by ASME Code

b/a values in table are based upon ASME Code

Acknowledgment

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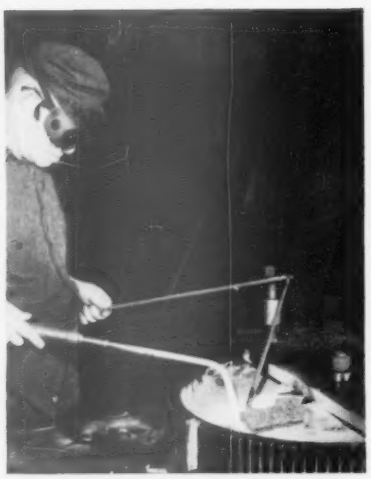
WELDING CLINIC

J. Imperati and R. F. Pulver, Welding Engineers
The American Brass Company, Waterbury, Conn.

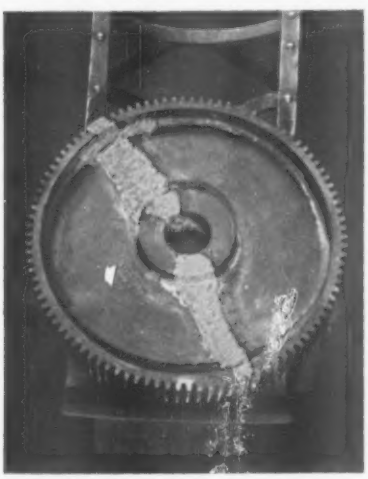
Braze Welding repairs saved this cast iron gear—and 2 to 4 weeks' production time

1. When a key came out and fell in the motor pinion of a big sheet mill flattener, this cast iron gear broke in half. Delivery on a new gear was 3 to 5 weeks. Braze welding repairs could return the machine to production in about a week.

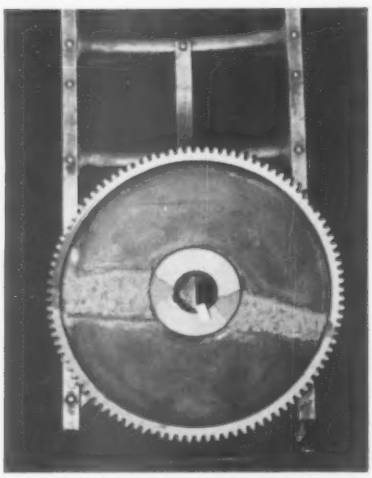
2. To save production time, it was decided to repair by braze welding. The 30″ diameter gear with a 3″ gear face and 1″ thick solid web was prepared by chipping and grinding bevels on edges of the fracture from both sides. This took 11 man-hours.



3. The gear was preheated to 800 F with an oxypropane torch. Then the fracture was braze welded, and the damaged gear face built up to full diameter with Anaconda-997 (Low Fuming) Bronze Welding Rod. Total welding time, 14 man-hours.



4. After a period of slow cooling, the welded gear was ready for a trip to the mill's machine shop. Here it was trued up and new teeth were cut in the built-up bronze weld metal. This phase of the repair required only 15 man-hours.



5. The repaired gear on its way back to the sheet mill flattener in less than a week. The machine was reassembled and back in production in just one week for a total saving of two to four weeks of valuable production time.

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